The Encyclopædia of

Municipal and Sanitary Engineering

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A HANDY WORKING GUIDE IN ALL MATTERS CONNECTED WITH MUNICIPAL AND SANITARY ENGINEERING AND

Administration

EDITED BY

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NEW YORK

D. VAN NOSTRAND COMPANY

23 MURRAY AND 27 WARREN STREETS

1910

PREFACE

In the present day the constant addition to the duties and responsibilities of local authorities imposes upon them many new departments of work, and at the same time intensifies existing powers and obligations in all matters of municipal and sanitary engineering.

It has thus become well-nigh impossible for those interested in local administration to keep themselves informed, even in general outline, on the many and varied subjects to which attention is now demanded by the State. The requisite information can only be gained by the expenditure of time, labour, and money in searching through a mass of literature mainly in the form of papers and reports.

For the first time such information is presented in dictionary form, convenient for immediate reference. To further facilitate this, the longer articles are divided into sections, the order of which, as well as the pith and scope of the article, being shown by a brief index at the head. Acts of Parliament affecting the various subjects dealt with are quoted when necessary, and a careful system of cross-referencing has been followed in order that the reader may rapidly acquire information on the cognate aspects of a subject.

The work has been prepared by many leading experts, whose experience in the matters with which they deal is well known; but the information has been gathered from all parts of the world, and the Editors tender cordial thanks to all those engineers and local authorities who have so readily placed the results of practical experience at their disposal.

The Editors desire to record the assistance they have received from Mr. G. Cadogan Rothery and Mr. C. F. Tweney in planning and editing "The Encyclopædia."

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THE ENCYCLOPÆDIA
OF
MUNICIPAL AND SANITARY ENGINEERING.

Abattoirs.—**Acts of Parliament—Site—Accommodation — Lairs and Pens — Slaughter-houses — Tripe - Dressing Department — Pig Department—Refuse Removal—Water Purification—Inspection Lairs—Hospital for Diseased Animals—Entrance Lodge—Cost.**

Acts of Parliament.—The following are the Acts of Parliament relating to slaughter-houses : Markets and Fairs Clauses Act, 1847 ; Towns Improvement Clauses Act, 1847 ; Public Health Act, 1875 ; Public Health (London) Act, 1891 ; Public Health Act, 1908.

The clause in the Public Health Act, 1875, reads as follows :—

"Any urban authority may, if they think fit, provide slaughter-houses, and they shall make bye-laws with respect to the management and charges for the use of any slaughter-houses so provided." "For the purposes of enabling any urban authority to regulate slaughter-houses within their district, the provisions of the Towns Improvement Clauses Act, 1847, with respect to slaughter-houses, shall be incorporated with this Act." "Nothing in this section shall prejudice or affect any rights, powers, or privileges of any persons incorporated by any local Act passed before the passing of the Public Health Act, 1848, for the purpose of making and maintaining slaughter-houses." (38 & 39 Vict. c. 55, s. 160.)

Site is the foremost consideration, and the place selected should be near the cattle market, or in conjunction with it, so as to prevent the long journey through the town for the cattle, to inconvenience them as little as possible, and to prevent the loss of weight which an animal suffers on a long journey. The site should also be either near or alongside a railway siding or waterway wharf, for precisely similar reasons. For the easy and cheap conveyance of the dead meat to the butchers' shops and cold storage, it will be necessary to have the slaughter-house in as central a position as possible. The approach roads to the site should be as wide as possible, allowing the cattle an easy passage to the lairs. The laying out or planning of the site is a very important point, and care must be exercised to group the whole accommodation for each class of cattle. There appears to be little doubt that the large slaughter-house is much the better idea; the system of having a number of small slaughter-houses, each to be used by one butcher, having many disadvantages and lending itself to serious objections, owing to the inability to properly inspect the meat before it is removed. The planning and construction of the two types are practically similar; and we will confine ourselves to the single large slaughter-house and the necessary buildings adjoining.

Accommodation.—In designing a public slaughter-house, it is usual to provide for the following accommodation: (1) Lairs for cattle; (2) pens for sheep; (3) slaughter-house; (4) tripe - dressing department; (5) pig - killing department, consisting of sties, covered yard, scalding-house, tripe - dressing department, and a meat-dressing department; (6) cold storage (sometimes); (7) refuse receptacle and

destructor; (8) water purification plant; (9) inspection lairs for cattle before being slaughtered; (10) hospital for cattle under observation, with slaughter-house attached; (11) porter's or superintendent's lodge and administration block, including office and weighing machine.

It will be seen that a well-appointed abattoir contains many departments; and it will therefore be impossible in the present article to go fully into the details of each department. It is proposed, however, to bring out the general principles in planning, and state the requirements necessary in this class of building. We will now deal briefly with each portion of the accommodation, proceeding in the order set out above.

1. Lairs for Cattle.—The places where the animals are rested previous to being killed. They should be placed as close as possible to the slaughter-house, but should not enter directly into it, but into a passage or corridor leading into the slaughter-house. It is usual to make the lairs of sufficient size to accommodate three days' meat supply. The paving should be of hard impervious materials, *e.g.*, asphalte; but in the corridor granite setts are best, as the beast struggles when he "smells blood"; and asphalte is rather too slippery. The walls for six feet from the floor should be lined with hard smooth material, *e.g.*, iron. The lairs must be well ventilated, lighted, and drained. The upper part may be used for storage purposes. In the lair, water and hay troughs should be fitted for feeding purposes.

2. Pens for Sheep.—These should be constructed and arranged in an exactly similar manner as the lairs for cattle.

3. The Slaughter-house.—There are two systems upon which this may be designed: (*a*) A number of small complete slaughter-houses; (*b*) one large hall. The latter form ensures much more cleanliness and more efficient supervision of the meat, and for these reasons alone it is to be recommended. The hall should be large enough to allow for killing three days' meat supply in one working day. All cattle, large and small, may be killed in this large hall—also sheep. The hall should, where possible, face the north, be in close connection with and easy of access to the cold storage, tripe-dressing, and the cattle lairs and sheep folds. Light and ventilation must be plentiful; and protection from the heat of the sun is very necessary. Floors should be of hard, impervious material, and walls should be of light colour. It is usual to line the walls for a height of six feet with white glazed bricks, this allowing great facilities for cleansing. Drainage must be carefully considered, no gullies or gratings being permissible in the slaughter-house. The floor should have a good fall towards the large doors through which the dead meat will be carted. Along the side wall an open channel should be constructed, delivering on to gullies outside the building, with gratings over, to prevent solids entering the drain. This drain should be carried to the water-purification plant, and the contents purified before being turned into the town sewer. The necessary killing rings must be placed in convenient positions in the floor. Doors should be made sliding, not folding. Water should be laid on in plentiful supplies, stand-posts being erected to each "killing bay." The walls must be strong enough to carry the girders which support the winches and necessary hoisting and travelling gear. The necessary lavatory accommodation for the users of the slaughter-house must be provided near by.

4. Tripe-dressing Department.—This should be provided close to, and opening out of, the slaughter-house, and fitted with basins with running water, scalding coppers, dressing and scrubbing tables, and hot and cold water basins. Steam will be plentiful, and ventilation must be effective to carry this off. Light must also be plentiful. The floor and walls must be hard and washable, and similar to those of the slaughter-house.

5. Pig Killing Department.—This department is quite separate from the other portion of the abattoir, and consists of:—(*a*) Pig-sties for each butcher capable of holding three days'

supply of pork, adjoining which, and separated by a gangway, are the (*b*) Killing and bleeding pens, which are covered over. (*c*) Scalding house, which is close to the killing yard, and must be provided with scalding coppers fed by hot water. Hoisting gear on travelling trolleys should be provided, by which the dead pig may be hoisted over the copper, plunged in, and then run on to the dressing house which adjoins. (*d*) Dressing house. This should be provided with plenty of suspension hooks on which to hang the meat. It should adjoin, or be close by, the cold storage, so that the meat may be transferred to this part for storage after being dressed. (*e*) The tripe-dressing department, adjoining the dressing house should be fitted up in a similar manner to that described for cattle. Store room for tools, dressing rooms for butchers, and lavatory accommodation should also be provided.

6. Cold Storage.—This is essentially an advantage for the private butcher. It must be in close proximity to the cattle and pig slaughter-houses, and comprise cold-producing machinery room, coal stores, boiler-house, and annexes or antechambers. It should be capable of holding three days' supply of meat, open direct on to the yard, with large sliding doors, and be so lighted that light is obtained and heat excluded. It should be placed, if possible, on the north-eastern side of the site with the south and west sides adjoining the slaughter-house, or some part of the buildings. Overhead pulleys travelling on rails must be provided for the conveyance of meat. All the inside faces of the walls should be lined with glazed bricks or tiles for the full height.

7. Refuse Disposal.—Ample means must be provided for the disposal of the refuse, and the most effective way appears to be the Pohlwil apparatus — a German invention. This system has been fitted up in duplicate at the City of London abattoir, Islington. The process is as follows:—The machinery consists of a steam-tight cylinder made of boiler plates, and fitted with hopper inlet and outlet with screw-down cover, steam connections, pressure gauge and safety valve, and provided inside with steel rollers. All the diseased carcases (which must be cut up), including skin, bones, and all offal, is inserted into the cylinder through the hoppers. The cover is then screwed down and steam injected under pressure. After a certain time, the cylinder is made to revolve and the inside cylinders also revolve, thus crushing up the whole of the contents into a fine brown powder. The cylinder is stopped, the cover removed, and the apparatus started again slowly, when the powder falls into a pit below. The great advantage of this system is that *all* the refuse of whatever description may be shot into the cylinder. The powder may be sold as a manure and is rich in fertilising qualities.

In many abattoirs the refuse is disposed of either by burning or carting away in wagons. In any case the building used must be isolated, but in a central position, closed and well ventilated, and lighted by a top light. Near this may be placed the tripe-washing troughs.

8. Water Purification Plant. — Before turning the contents of the drains into the main sewer or river (if one adjoins or is near the building), it should be put through a purification process.

9. Inspection Lairs.—Near the entrance to the abattoir should be placed inspection lairs for the cattle and pigs, so that they may be inspected by the veterinary surgeon previous to transit to the "killing lairs." Suspected cattle and pigs should then be passed on to special detention lairs, and diseased ones on to the slaughter-house and premises for such.

10. Hospital for Diseased Animals.—This should be entirely isolated from the other building, and consist of lairs and slaughter-house, with meat store attached, so that carcasses which are discovered to be diseased may also be stored in it.

11. Entrance Lodge. — A small house should be provided for the superintendent of the abattoir, to which may be attached a weigh office, office for medical officer or veterinary surgeon, meter-house for gas or electric light, and store room for tools, &c.,

and near, or adjoining the offices, should be placed the w.c. and urinal accommodation, and, in some cases, waiting rooms for drovers and cattle dealers.

Cost.—This, naturally, varies for different towns. Some have small abattoirs, which supply the needs, whereas others, *e.g.*, Birkenhead, have one on a very extensive scale.

On referring to the returns collected from different towns, the cost appears as follows:—

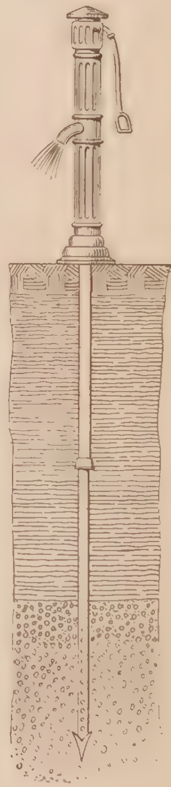
Preston	costs about	11*d.*	per head of	population	
Birkenhead	,,	2/6	,,	,,	,,
Carlisle	,,	3/6	,,	,,	,,
Leeds	,,	1/2½*d.*	,,	,,	,,
Paisley	,,	1/6½*d.*	,,	,,	,,

R. H. B.

A. B. C. Process (Sewage Treatment).—The precipitants used in this process are alum, blood, clay and charcoal. The blood is now omitted and it is probable equal results would be obtained by the alum alone. The process is used at Aylesbury and Kingston-on-Thames. A "native guano" is made from sewage by this method at Aylesbury, but there is considerable difference of opinion as to the commercial value of the product. The effluent is reported very pure, and the process appears to be carried on without nuisance. The quantity of sludge produced is considerable, and at Kingston this is disposed of by the Native Guano Company.

Absolute-rest precipitation tanks.—This type of tank is not used to any very large extent owing to the amount of fall and tank accommodation required. The "continuous-flow" tank is more generally employed. After settlement in the absolute-rest tank, the top water is gradually drawn off by floating arms down to the level of the precipitated sludge, the latter being let off through a sludge-penstock. With quiescent sedimentation, two or three hours' settlement is usually sufficient to yield a fairly satisfactory tank liquor. The tanks should be used in parallel, and the sludge should be frequently removed.

Abyssinian tube wells.—These consist of iron tubes from 1¼ in. to 4 in. diameter driven into the ground until the subsoil water is reached for the purpose of quickly obtaining, by means of a pump fixed at the top, a temporary supply of water. Wells of this description were first extensively used during the Abyssinian campaign, hence the name by which they are now popularly known. These wells are also known sometimes as *Norton's tube wells*, and *American tube wells*. The iron tubes are driven into the ground in lengths by means of a "monkey" — the first tube having a hard steel nozzle, the lower 2 feet of the sides of the tube being perforated. Successive lengths of tube are screwed on and driven until the necessary depth is reached. Such tubes have been satisfactorily put down to as much as 150 feet depth, but the usual limit is about 50 feet. The most suitable strata for obtaining water by this means are the chalk, gravel, and coarse sand where well saturated. The system is not suitable in fine sand, clay or marl, and the tubes cannot, of course, be driven through hard rock beds. After the tubes have been driven and water has been reached a hand-pump is attached and the yield of the well and quality of the water tested. Should the results prove unsatisfactory the well may be driven deeper, or the tubes withdrawn and redriven at another likely site. Abyssinian tubes are sometimes advantageously driven at the bottom of ordinary sunk wells for the purpose of increasing the yield. Where favourable conditions exist, a driven tube well affords a cheap, ready and safe means of securing temporary supplies. The quantity of water obtainable



Abyssinian Tube Well.

will vary greatly according to the conditions of the site, nature of the strata, depth of well, and capacity of the pump, but if favourably placed a $1\frac{1}{4}$ in. diameter well may be expected to yield from 150 to 600 gallons per hour, a 2 in. diameter from 300 to 1,500 gallons, and a 3 in. diameter from 500 to 2,500 gallons.

The cost of tube wells also varies according to the circumstances to be dealt with, but under ordinary conditions in gravelly ground a $1\frac{1}{4}$ in. by 30 ft. well may be expected to cost about £10, or 7*s*. per foot of depth, including all expenses of labour, materials and cartage. A 2 in. by 30 ft. well would cost under similar circumstances about £15, or 10*s*. per foot of depth. W. H. M.

Access Pipe.—A pipe having an air-tight, removable lid or a manhole giving access to the interior of the pipe and thence to the drain, soil, or waste pipe upon which it is fixed. Such pipes are most usefully provided at bends and junctions to provide means for clearing obstructions and for cleaning purposes. (*See also* CLEANING EYE.)

Accumulator (hydraulic).—An appliance for storing water under pressure, whereby very heavy work may be accomplished in a short time. It consists of a long vertical cylinder fitted with a weighted ram, which works, water-tight, through a stuffing box and gland at the top. By pumping water into the bottom of the cylinder the ram with its weight is raised, and the pressure due to the same may be utilised for driving hydraulic cranes, lifts, riveting or other machines, where the work is of an intermittent nature. The water supply to the cylinder is automatically regulated by causing the weight to strike levers, so arranged that when the cylinder is full and the ram at the top of its stroke, the forcing pumps are stopped; when approaching emptiness through the use of the water, the pumps are started again by the descent of the ram.

The pressure per square inch will be equal to the total weight in lbs., including that of the ram and the connections that move with it, divided by the cross-sectional area of the ram in square inches. The work stored in the accumulator is equivalent to the total weight in lbs. multiplied by the height in feet through which it is raised; less a slight fractional loss in each case. The usual working pressure for cranes and lifts is about 750 lbs., for machine tools 1,500 lbs. and upwards per square inch. E. L. B.

Acetylene.—Acetylene is a colourless gas, having a sweet ethereal smell. As ordinarily made it has a peculiar penetrating odour like that of garlic, due to the impurities which it contains. Chemically, it is an unsaturated hydro-carbon, having the formula C_2H_2, and containing by weight 12 parts of carbon to 1 of hydrogen. Its specific gravity is 0·9, that of air being taken as unity. At 62° F. 1 cub. ft. = 0·0685 lbs. and 1 lb. = 14·6 cub. ft. It is slightly soluble in water, 10 volumes of which at 62° F. dissolve 11 volumes of acetylene. If, however, the water is saturated with salt, 20 volumes of it dissolve only 1 of the gas.

Acetylene may be prepared in various ways, but for practical purposes it is obtained from calcium carbide, a hard greyish substance, generally of a fine crystalline texture, which is made by reducing quicklime with coke in the electric arc. The reaction is as follows:—

$$\underset{\text{Quicklime.}}{CaO} + \underset{\text{Carbon.}}{3\,C} = \underset{\text{Calcium Carbide.}}{CaC_2} + \underset{\text{Carbonic Oxide Gas.}}{CO}$$

The specific gravity of calcium carbide is 2·22, and it contains five parts of calcium to three of carbon.

When calcium carbide is brought into contact with water, the following double decomposition takes place:—

$$\underset{\text{Calcium Carbide.}}{CaC_2} + \underset{\text{Water.}}{H_2O} = \underset{\text{Quicklime.}}{CaO} + \underset{\text{Acetylene.}}{C_2H_2}$$

The quicklime at once combines with the excess of water to form slaked lime, $Ca[HO]_2$. Theoretically, the quantity of water required

is under half a pint per pound of carbide, but in practice a pint must be supplied. Theoretically also 1 lb. of pure carbide should give 5·93 cub. ft. of acetylene. In practice 5 cub. ft. is a good output; but yields up to 5·22 cub. ft. are claimed.

Acetylene burns with a brilliant and steady flame, and during the past ten years has come into extensive use for small lighting installations. In this country alone some 300 forms of generator have been patented, of which about one-tenth have been placed on the market. A good generator should work at a low temperature and a low pressure, and should effect a complete decomposition of the carbide, so as to give a maximum yield of gas. The latter may be generated either by allowing the water to drip on to the carbide, or by dropping the carbide in small pieces into the water, the latter method possessing several important advantages. Two or three horizontal screens or gratings should be placed in the water to catch the carbide, and prevent it from dropping into the lime sludge which settles at the bottom.

Generators are either "automatic" or "non-automatic," the former making the gas only as required for use, and the latter continuously. With non-automatic generators holders must be provided to store the gas whenever the demand falls short of the supply. This form of generator is to be preferred.

Commercial calcium carbide is never pure, and the resulting gas likewise contains traces of other substances; the chief impurities being phosphuretted and sulphuretted hydrogen and ammonia. The gas should, therefore, be passed through a purifier before use.

Acetylene has a high calorific value, namely, 1,504 B. T. U. per cubic foot, exclusive of the heat latent in the water vapour due to combustion. A cubic foot of the gas requires for complete combustion about 12 cub. ft. of air, the products being carbonic acid gas, water, and nitrogen. A mixture of acetylene and air is explosive when the proportion of the former is anywhere between 3 per cent. and 82 per cent. of the whole. The gas alone will explode when subjected to sudden compression.

Composition tubing should never be used to carry acetylene, and the pipes should be of the best iron barrel, not less than $\frac{3}{8}$ in. in diameter. The pipes may be somewhat smaller than for coal gas.

When acetylene is burnt in ordinary gas-burners the flame smokes, and large quantities of soot are deposited. The best results are obtained from special burners with steatite tips, so formed that the gas is shielded from the hot nipple by a layer of air. The flame is small, white, and intensely bright, and owes its luminosity to the incandescent particles of carbon which it contains. The amount of light obtained from acetylene varies with the make and size of the burner, ranging from 24 candles per cubic foot with burners consuming $\frac{1}{2}$ cub. ft. per hour to 40 or 48 candles with 1 cub. ft. burners. The larger burners are, therefore, the more economical. For equal volumes acetylene gives many times as much light as coal gas burnt in a flat flame burner, and from $1\frac{1}{2}$ to $2\frac{1}{2}$ times as much as coal gas used with a good incandescent mantle. Light for light it consumes more oxygen, and evolves more CO_2 and heat than an incandescent gas-burner, but very much less of each than the old flat flame burner with coal gas.

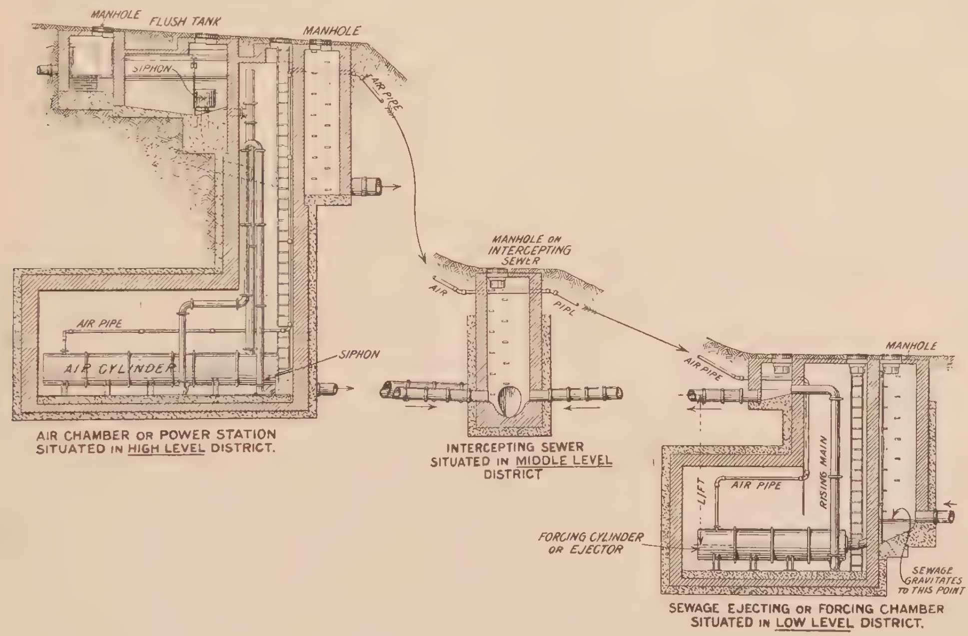
With calcium carbide at its present price acetylene cannot compete with coal gas used with Welsbach mantles; but its brilliancy and convenience will ensure its adoption in many situations where coal gas is not obtainable.

A. J. M.

Adams' Sewage Lift.—This is an apparatus in which high-level sewage is applied to the work of raising low-level sewage to an intermediate, or middle level, intercepting sewer. High-level sewage enters the "flush tank," which discharges its contents through a siphon, followed by a drop-pipe, into the "air-cylinder" shown below, thus displacing the air contained in the latter, and

forcing it through an "air pipe," which conveys it to the "forcing cylinder" or "ejector" situated some distance away in the low-level district. This air is there utilised to drive out the liquid contents of the "forcing cylinder" through the rising main shown in the figure. After having been thus lifted the sewage gravitates to the nearest middle-level intercepting sewer. The "air cylinder," after having been charged with the liquid contents from the "flush tank," is emptied by means of a siphon shown in the illustration, and thus prepared ready for the next charge from the "flush tank." The liquid delivered by the siphon from the "air cylinder" and the sewage from the rising main off the ejector are both delivered by gravitation to the middle-level intercepting sewer.

Where high-level sewage is not available the town water supply is sometimes used to give the necessary head for creating the requisite pressure of air, but this obviously adds to the working cost of the system. The quantity of liquid used to raise a given volume of sewage varies according to local conditions, the height of the lift, &c., from 60 per cent. up to 500 per cent., or more for high lifts. The system is also applicable to raising sewage of underground conveniences, basements situated below sewer level, and such like. It is in operation at Douglas, Ilkley, Bowness, Crayford, and other places.



Adams' Sewage Lift.

Aërating Tiles (for Bacterial Bed Floors).—Aërating floors are most satisfactorily formed by constructing a floor of concrete 6 in. or 9 in. thick, according to the nature of the foundation, and then overlaying the same with a false or hollow floor of *aërating tiles.*

Such a floor affords the best opportunities

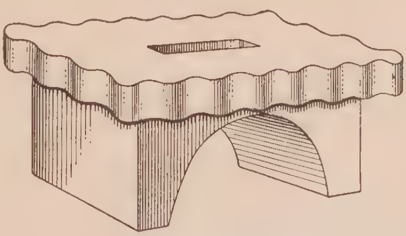


Fig. 1.—Ames' Aërating Tile for Bacteria Beds.

for the thorough and uniform aëration of the superincumbent filtering medium, which is now recognised to be an essential feature in the efficient working of bacterial methods of purification. The tiles now used in this connection are of great variety of design, but all have a similar object in providing a strong open flooring so as to admit of the free circulation of air and at the same time afford adequate support for the superincumbent filtering materials. The three tiles illustrated are respectively of Ames', Mansfield's, and Stiff's pattern, but there are many other varieties. They are usually made of stoneware or hard burnt Staffordshire clays, and, though they need to be of ample strength, should not be heavier than absolutely necessary, otherwise the cost of carriage will render the flooring expensive. The "Mansfield" tile is simple and efficient, and, in the writer's experience, costs from 2*s.* 6*d.* to 2*s.* 9*d.* per square yard laid complete.

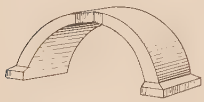


FIG. 2.—Mansfield Aërating Tile.

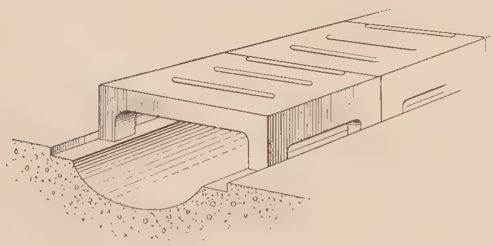


FIG. 3.—Stiff's Aëration Drainage Channels.

Aërobic and Anaërobic (Treatment of Sewage).—These terms, which are applied to two different classes of bacteria, simply mean "living with air" and "living without air." In 1861 Pasteur discovered that many bacteria could live, and even set up active fermentation, in the absence of oxygen, and he, therefore, gave these organisms the name of *anaërobes.* His statements, being soon corroborated, resulted in the classification of bacteria into two groups—the *aërobes* and the *anaërobes.* To the aërobes are due the conversion of urea into ammonia, and ammonia into nitrate. To the anaërobes is attributed the decomposition of cellulose and allied substances with evolution of marsh gas, the removal of oxygen from nitrates with simultaneous oxidation of organic matter, and the decomposition of complex organic matter, with production of ammonia, hydrogen, and other substances.

In sewage purification the work of the anaërobic bacteria is mostly done in the sewers and in the septic tank, whilst that of the aërobic class is confined mainly to the percolating beds. In contact beds both aërobic and anaërobic conditions obtain according to the alternating periods of rest and work.

Fischer in "Structure and Functions of Bacteria" states that in the aërobic bacteria the process of respiration is the same as in all ordinary organisms. They absorb oxygen and with it break up non-nitrogenous bodies, such as glycerine or sugar, into carbonic acid and water. They are also able, like plants and animals, to assimilate nitrogenous substances, such as peptones and amido compounds, although with less gain of energy and less easily than they can carbonaceous bodies. Many of the *aërobic bacteria* are totally unable to live without oxygen, and when deprived of it die, as would a mouse in pure hydrogen. They are exclusive, or *obligatory aërobes.* Contrasted with the obligatory aërobic bacteria we have the obligatory anaërobic forms, which thrive only in the absence of oxygen, small traces of this gas being sufficient to inhibit growth. Between these extremes there is a great host of bacteria representing every gradation between the two modes of life. These are the *facultative anaërobes,* which, while growing best with a plentiful supply of oxygen, are nevertheless able to exist with a very small amount, and even with none at all, although in this case their vitality is often much impaired. Anaërobic bacteria, both obligatory and facultative, are found everywhere in Nature where the air cannot penetrate, or where it is replaced by other gases in the

deeper layers of the soil; for instance, in the mud of rivers and standing waters, or the ooze of the sea bottom, and in manure. In all such places anaërobic bacteria are the principal, and often the only, forms of life, and by the fermentative and putrefactive processes they set up they effect the disintegration and removal of dead animals and plants.

W. H. M.

After-flush.—A small quantity of flushing water discharged into a closet basin after the main flush from the cistern has been expended. Its object is to ensure that the closet trap is fully charged.

Air Compressor.—When air is required at a very moderate pressure a steam engine can be made to serve the purpose of a compressor, in which case the air is drawn in through the "exhaust" port and delivered through the "inlet" ports—the valve setting being modified to suit the circumstances. For any pressure over about 20 lbs. per square inch, the cylinder, and especially its ends, must be water-jacketed in order that the heat due to the compression of the air may be carried off. Slide valves are unsuitable in this case, and their place is usually taken by disc valves automatically lifted from their seatings by the suction and discharge of the air, like those of a pump. The suction valves are made as light as possible and of comparatively large diameter, and are fitted with very light springs, so that they may open readily and not "wire-draw" the incoming air, and also close with a minimum of shock. To ensure a full cylinder and to diminish resistance the valves are, in some cases, opened "positively" by means of cams in the same manner as those of gas or oil engines. Equally important is the reduction of clearance spaces to the lowest practicable degree, as any compressed air remaining in the cylinder or valve passages, after the piston has completed its stroke, represents wasted work.

The chief source of loss in an air compressor is due to the fact that the heat is removed *after* instead of *during* compression, with the result that much of the work has been uselessly spent in producing heat which is afterwards dissipated. This loss may be greatly reduced by dividing the work into stages, in which case the air is compressed to a certain point in one cylinder, then cooled by passing through pipes surrounded by water and afterwards further compressed in another cylinder. Two or more stages, with intermediate cooling, are adopted according to the range of pressures.

Air may also be compressed by the direct action of falling water; this method is in use at several of the large waterfalls in America and Canada. (*See* "COMPRESSED AIR.")

E. L. B.

Air, Atmospheric, Purity of.—Air is a mixture, composed approximately of oxygen, 21 %; nitrogen, 78·06 %; and argon, 0·94 % by volume. Traces of hydrogen, carbon dioxide, ammonia, and ozone, as well as of the rare elements krypton, neon, coronium, and others, are normally present in the atmosphere, with a variable amount of aqueous vapour and dust. The most important impurities are as follows:—

MICRO-ORGANISMS AND DUST.—These are by far the most dangerous impurities to be dealt with. Air free from dust probably exists only as a laboratory product. Dust is partly organic and partly mineral; it includes particles of soil, vegetable matter, animal substances, micro-organisms, particles of sea salt, volcanic and meteoric dust, soot and other matters discharged from chimneys, pollen of grasses and flowers in the country. According to Aitken, there are 300 to 3,000 dust particles in a cubic centimetre of country air, from Argyllshire; whereas that of London contains 48,000 to 150,000 per cubic centimetre. Mineral dust is found in all parts of the atmosphere; organic only in the lower strata. Micro-organisms are usually absent from the air at an altitude of over 6,500 feet and over

the ocean beyond 120 miles from land. The air of cities is rich in micro-organisms. The importance of dust as an impurity lies in its power of disseminating disease, and its effect in the production of rain and fog. Without dust in the air it appears certain that we could have neither rain nor fog, as a nucleus is required for each drop of water.

Carbon Dioxide exists in normal air to the extent of about 3 parts in 10,000, not 4 parts as is often stated. It results from the oxidation of organic matter, as in respiration and combustion. It has now been shown to be inert and non-poisonous, and acts only by displacing oxygen. Its presence is, however, used as an indicator of pollution from other causes, and 6 or 7 parts per 10,000 is considered the permissible limit.

Carbon Monoxide.—This is a colourless and odourless gas, very poisonous, and having the same density as nitrogen. It is found usually as the result of imperfect combustion, or a coal-gas leakage; 1 part in 400 of air causes poisoning, and 1 % is rapidly fatal.

Sewer Gas.—When present in the air in large quantities, sewer gas is known to have the effect of lowering the power of resistance of the human system to disease, and is moreover objected to on account of its characteristically unpleasant smell.

Aqueous Vapour.—This is a very important constituent of the air, but can hardly be called an impurity. In the form of fog in smoky cities it is very injurious to health, although the evils arising from such fogs depend on the sulphur acids and solid matter held by the water rather than on the water itself. When the atmosphere is very damp, or approaching its saturation point, evaporation is impeded, the effects of heat and cold are more felt, and depression and other unpleasant sensations are experienced. The degree of saturation is called the "relative humidity," it is usually 60 to 75 %.

Other impurities may result from special trade processes, and under particular conditions, as in mines; but the above are those of most importance under ordinary circumstances in civilised countries.

J. S. O.

Air-Lift.—A method of raising water, petroleum, &c., from tube wells, by means of

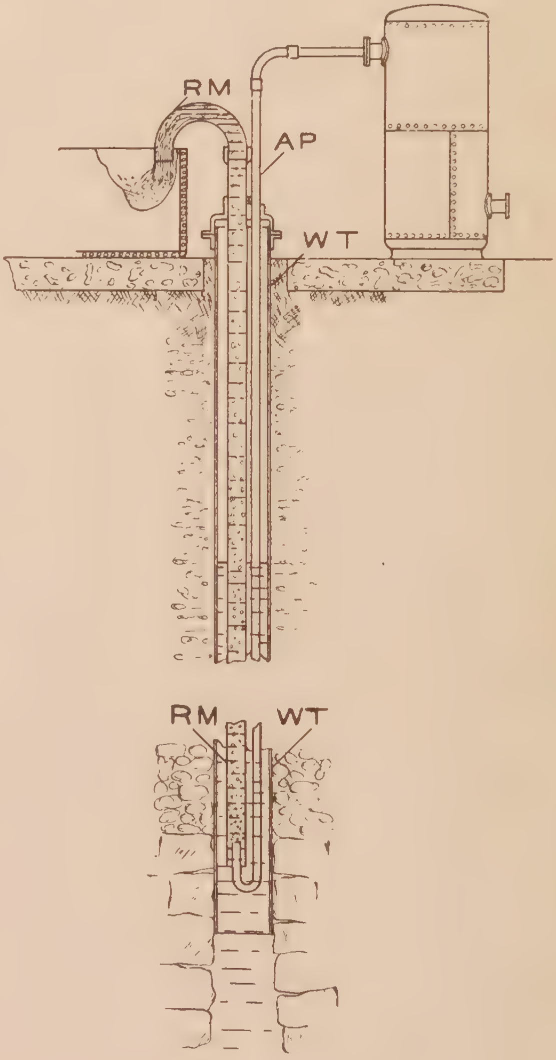


Fig. 1.

compressed air. The apparatus is extremely simple and usually consists of two pipes

lowered into the borehole—one for conveying compressed air, the other for carrying the water to the surface; both pipes are submerged to a certain depth in the liquid o be raised. Referring to Fig. 1, *A. P.*

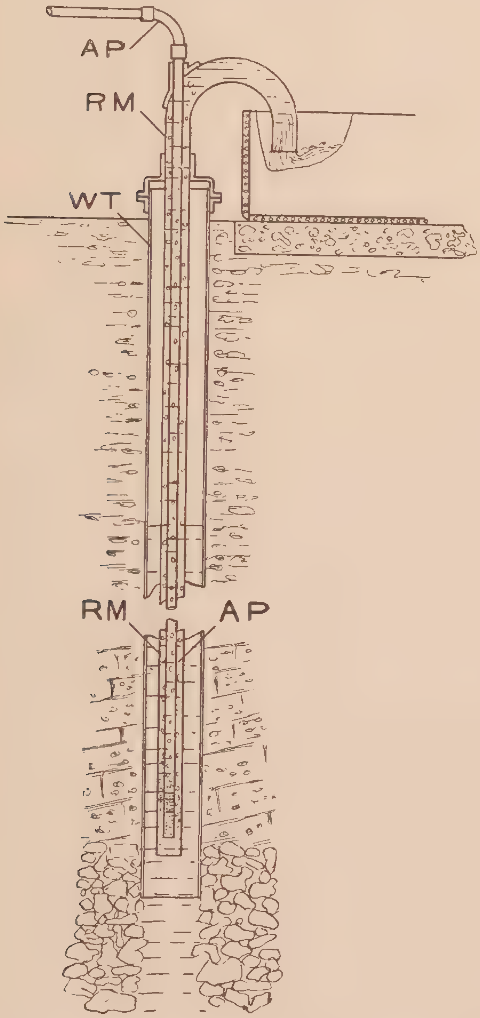


Fig. 2.

represents the air pipe, *R. M.* the water pipe or rising main, and *W. T.* the well tube. In some cases the air pipe is placed concentrically within the rising main (Fig. 2). When the well tube is of sufficient depth and suitable area, it may itself serve as a rising main. The working principle is as follows:—Air is forced down the pipe *A. P.* and allowed to escape, at the bottom, into the water contained in the rising main *R. M.* This aërates and, therefore, reduces the specific gravity of the contents of *R. M.*, with the result that the liquid is pressed or floated upwards by the superior weight of the column of non-aërated liquid outside it; as this leads to a constant replenishment of the rising main the liquid rises in a continuous stream. The drawings show the form of nozzle used by Dr. Pohlé, the reintroducer of the system. Since that time various improvements have been made in details; most of them consist in discharging the air through a narrow slit in order that it may more thoroughly mix with the liquid and avoid the formation of large bubbles which are apt to slip through the water without doing their share of work and also cause a pulsating delivery. A recent improvement is to employ a tapered rising main (Price's Patent) which allows the air to expand laterally and permits the velocity of the water to be more uniform. The air acts entirely by volume as it has only to impart buoyancy to the water, but in order to escape into the rising main it must be supplied at a pressure just sufficient to overcome that due to the column of water above the nozzle. As this pressure diminishes as the top of the pipe is approached the bubbles of air expand (isothermally) as they rise and escape, at atmospheric pressure, at the outlet. If the water, after being raised, has to be taken in a lateral direction it should be allowed to flow there by gravity from an open tank, into which the rising main discharges, otherwise there will be a difficulty in getting rid of the air. The "submergence" or depth that the nozzle has to be immersed in the water contained in the borehole is governed by the height of the lift, in other words, the distance from the *working* level of the water in the well, to the height to which it is to be raised. In practice this varies from one and one-third to about twice the lift. Generally speaking, the deeper the submergence the greater is the

economy, as less air is wasted; on the other hand the borehole must be correspondingly deepened and the air pressure increased in proportion. Although the efficiency is low, seldom reaching 40 % under the best conditions, its great simplicity and convenience, coupled with the fact that more water can be raised by this system, from a given sized borehole, than by any other means, give it an important place amongst water-raising appliances. The system is in use for public water supply purposes at the Birkenhead and Tunbridge Wells Corporation Waterworks. (*See* "Compressed Air," "Air Compressors," "Hydrostatic Head.")

E. L. B.

Air Vessel.—(*See* "Pumps and Pumping Machinery.")

Algæ, Growth in Water Supplies.—Numerous low forms of vegetable life may occur in potable waters, and many of these it is impossible to classify or to identify. During their life history some assume several different forms, and frequently free swimming cells are found which may belong to the animal kingdom or may simply be the spore form of an algæ, or of a fungus. Practically all the extremely small organisms which contain chlorophyll are algæ, and Cooke's definition of these may be accepted as most useful for all practical purposes. "Algals, or Algæ," he says, are "cellular flowerless plants, for the most part without any proper roots, or mycelium, living, with rare exceptions, entirely in water, and imbibing nutriment by their whole surface, from the medium in which they grow." Just as the colouring matter of leaves varies from the darkest green to the brightest red, so the colouring matter in the algæ varies, but the great majority contain chlorophyll of some shade of green. In the absence of sunlight they cease to grow, light being essential for the formation of chlorophyll. Warmth encourages growth, cold retards it, and probably there is a range of temperature for each organism within which it can live but beyond which it will speedily perish. There is doubtless also an "optimum" temperature at which growth is most rapid. Many of these low forms of plant life produce spores, and these are far more resistent to adverse influences than the organisms which produced them, hence after all growth has apparently disappeared from the water spores may be lying dormant, capable of producing an abundant crop as soon as the environment is once more favourable. Whilst many are capable of growing in the purest of natural waters, there is no doubt that rapid proliferation is only possible where the water contains traces of impurity in solution. In large reservoirs algoid growths rarely prove troublesome, but occasionally for some unexplained reason some species will multiply with such enormous rapidity as to discolour the whole of the water, and on occasions impart to it an odour and taste. Usually the latter do not develop until the stage of rapid development is passed, then the nutriment in the water being exhausted or the conditions having become unfavourable, the organism dies, and in decomposing produces the compounds which impart the odour and taste. Apart from the trouble which may be caused by the development of any odour, these organisms when in unusual abundance rapidly choke sand filters, and cause grave inconvenience. Often when a water has been cleared from one class of organism others will, at a later date, appear. Thus in the Staines reservoir of the Metropolitan Water Board an enormous growth of *Oscillatoria* appeared in the autumn of 1907. By the use of copper sulphate these were removed, but in the spring of the following year *Asterionella*, *Synedra* and *Cyclotella* appeared and seriously impeded the process of filtration. Algæ are more prone to appear in uncovered small reservoirs, especially if fed by spring water. Covering so as to exclude light is the only effectual remedy. For further information

on this important subject consult Cooke's "Fresh Water Algæ" and Thresh's "Examination of Water and Water Supplies." Valuable information bearing upon the removal of algæ by copper sulphate will be found in a paper by Dr. Kemna in Vol. XI. of the "Transactions of the Association of Water Engineers." (*Vide also* section on "MICRO-ORGANISMS IN WATER.")

J. C. T.

Alloys.—(*See* "METALS.")

Alumina and Lime (treatment of sewage).—The sewage of the eastern district of the city of Glasgow is treated with the precipitants alumina and lime in the proportion of two of the former to one of the latter. The sludge, after the admixture of hot lime, is pressed into cake by means of sludge presses, and when mixed with street-sweepings and ashes is disposed of for manurial purposes. The cost of the treatment per million gallons of sewage is put at £3 8*s*.

Alumino-Ferric (Spence's) is a commercial sulphate of alumina containing a small proportion of sulphate of iron, used as a sewage precipitant with the after addition of lime. It should be free from much excess of acid, as this wastes the lime. The gelatinous alumina removes the suspended and some of the dissolved organic matter, and the iron removes sulphide. After sedimentation, a clear and colourless liquid can generally be run off, leaving a voluminous sludge. (*See* "PRECIPITANTS FOR SEWAGE.")

Ambulances.—**Acts of Parliament—Site—Accommodation — Accessories — Ambulances — Stretchers—Litters.**

ACTS OF PARLIAMENT.—Public Health Act, 1875; Isolation Hospitals Act, 1893.

SITE.—Ambulance stations are generally in conjunction with or near the police or fire station, the horses being then available for both purposes.

ACCOMMODATION.—Provision must be made for the housing of one or more horse ambulance vans, one or more hand stretchers, attendants' house, work room, harness room, stables for horses with store rooms and hay loft.

ACCESSORIES.—This article deals more particularly with the necessary appliances needed for street ambulance work rather than ambulance stations, and these consist of ambulance carriages and wagons, stretchers, and litters. Each apparatus will be briefly dealt with, including the materials used in its construction.

AMBULANCE CARRIAGES AND WAGONS.—It is a difficult matter to lay down hard and fast rules for the construction of these, as many points have to be taken into consideration, *e.g.*, the amount available for the supply of horses, the nature of the roads, &c. The horse ambulance is the one recommended by the St. John's Ambulance Association. "It is capable of carrying three patients on stretchers and one attendant inside. The stretcher and its mountings on the off side of the carriage can be removed, folded up, and attached to the roof, the cushion which was resting on the brackets designed for the purpose being removed. The upper stretcher on the near side is mounted on an elevator which can be lowered much on the principle of parallel rulers. This elevator can be removed, and, if made to fold up, can, with the stretcher, be attached to the roof. The lower stretcher and its mountings are also made detachable, and when removed, an omnibus remains, while, if desired, the whole of the fittings restore the vehicle to an ambulance for three stretcher cases. The dimensions of the body of the carriage are: height, 6 ft.; width, 4 ft. 6 in.; length, 6 ft. 4 in.: the well extending approximately 4 ft. 6 in. from the rear. A cupboard is available for surgical appliances when the off side stretcher is not in position, but this has to be removed when this stretcher is used." ("Municipal Engineer's Specification," 1905, p. 83.) The doors at the back of the carriage are hung folding and

should leave the whole of the back clear, to give easy access and facilities for getting the stretchers in and out.

Ventilation is obtained by having some of the small lights on the side made to open. The materials used in the construction are ash for the framework with mahogany panels, the well being made with birch sides and deal floor, the roof of pine covered with canvas and painted. Cushions should be stuffed with hair and covered with leather or waterproof canvas. The "Municipal Engineer's Specification," 1905, p. 83, gives the following different varieties of horse ambulances:

1. Van-shaped without a well.
2. Van-shaped similar to No. 1 but provided with a short well, room being left for the turning of the front wheels under that part of the body.
3. A similar vehicle with a long well, and a fore-carriage under which the front wheels turn.
4. Brougham shaped.
5. A light four-wheeled conveyance.

STRETCHERS.—These consist of a bed on which the patient reclines, poles and traverse bars and also feet, carrying straps, and straps for securing the patient, and a hood or covering of canvas. A stretcher generally weighs from 20 lbs. to 30 lbs.

BED.—This is generally about 6 ft. long and 22 in. wide. The bed is generally made of canvas, sail-cloth, woven wire, cane, or other suitable materials. It is advisable not to have the width more than 22 in., or transport by railway will be impossible.

The bed must be firmly fixed to the poles, though easily capable of being detached when necessary. Pillows or cushions may be provided.

POLES.—These may be of ash or pine, steel tubing, or wood and iron combined, and extend about 12 in. beyond the bed at each end. The upper side should be rounded to afford protection for the canvas. The handles may with great advantage be telescopic.

TRAVERSE BARS.—These are used to keep the poles apart and complete the framework on which the bed is fixed and kept tight. They are generally hinged to allow of the stretcher being folded up when not in use. The material is the same as the poles.

FEET.—These are generally of wood or iron and fitted with castors, to allow of the stretcher being pushed about. They should raise it about 6 in. from the ground.

STRAPS.—The carrying straps are made of either web or leather, and have adjustable loops for regulating the length for bearers of different heights. The straps for securing the patient are of the same material, and two or three in number, and for police purposes wrist straps are provided.

LITTERS.—The following is a specification of litters by the St. John's Ambulance Association appearing in the "Municipal Engineer's Specification," No. 1, 1905, p. 83, and if followed will give all the necessary requirements for this class of ambulance:—"Litters. The Ashford litter undercarriage is provided with two wheels 36 in. in height, usually with indiarubber tyres. It has a cranked axle to enable the stretcher-bearers to pass between the wheels instead of lifting the stretcher over them. It is fitted with four arms, capable of being used as legs or handles, which can be locked in either a horizontal or vertical position. A hood and apron are usually supplied as part of the litter."

R. H. B.

American Tube Wells.—(*See* "ABYSSINIAN WELLS.")

Amines Process (sewage treatment).—This is a chemical precipitation process, which, it is claimed, sterilizes the sewage. The precipitants used are lime and herring-brine, in the proportion of $22\frac{1}{2}$ grains per gallon of lime and 4 grains of the brine. Lime alone in large quantities inhibits putrefaction and nitrification. In 1891 the system was tried at Salford, on the continuous flow principle. The wet sludge amounted to about 26 tons per million gallons.

Anemometer.—The direction of the wind can be ascertained from the indication of a well-balanced vane or weathercock; or when this is not available by observing the drift of smoke. The velocity and pressure of the wind are recorded by means of anemometers. The instrument most generally used is the Robinson cup anemometer. In this instrument four hemispherical cups, fixed at the extremities of cross arms attached to a vertical axis, are caused to rotate by the force of the wind. By means of an endless screw the revolutions of the vertical axis are communicated to a series of wheels, which indicate on dials the number of miles of wind. The graduations have been calculated on the supposition that the velocity of the wind is three times that of the motion of revolution of the cups. Later experiments, however, have shown that this value is too high, and differs also with the size of the instrument. For anemometers with 9-in. cups and 2-ft. arms the factor is 2·2, and for anemometers with 5-in. cups and 1-ft. arms the factor is 2·8. The difference between consecutive readings of the dials gives the number of miles of wind which have passed the cups since the last reading. It is customary to express the rate of the travel of the wind in miles per hour. The instrument can be constructed to give a continuous record of the velocity of the wind. (For other forms of anemometers, *see* "WIND FORCE.")

W. M.

Anaërobic bacteria (in sewage treatment).—(*See* "AËROBIC AND ANAËROBIC.")

Anti-Siphonage Pipes.—(*See* "SIPHONAGE.")

Antiseptics are agents which retard or prevent putrefaction or decay. The difference between them and disinfectants is mainly one of purpose; the latter being directed to the destruction of the organisms of disease, and the former to the prevention of injury by microbial life to food or other commercial products. Nearly all *concentrated* chemical solutions hinder the growth of organisms, but many of them in weak dilution actually promote the development; instances are, salt, sugar, and acetate of potash. Disinfectants require to be antibacterial in a much weaker state. Another difference is that antiseptics as used in food must obviously be non-toxic. Since organisms only grow actively within certain limits of temperature and require water for their development, heat and cold outside those limits, or drying, act as natural antiseptics. Tinned goods are usually heated to boiling point or a little higher, but a temperature of 65-70° C., maintained for twenty minutes, kills nearly all bacteria though not their spores, and is sufficient to preserve milk for a reasonable time.[1] As to the effect of cold, flesh is preserved in commerce either as *chilled*, near freezing point, from 1 to 2° C., or for a longer time as *hard frozen*, from 9 to 18° C.; butter at temperatures down to 15° C., milk is frozen at 0·5° C., while fruits keep better just above freezing. Even at 10° C. bacterial multiplication is checked. Many organisms, however, survive even when cooled to − 252° C. (Macfadyen & Rowland), therefore decay can recommence when the temperature is raised.

Chemical antiseptics are numerous, and not all innocuous. Ordinary "smoking" dries the surface and also impregnates it with acetic acid, formaldehyde and creosote. In *salting* the antisepsis is subordinate to a process of diffusion whereby the salt, with sometimes nitre and sugar—neither of them strong antiseptics—pass inwards and displace the juices containing putrescible albuminoids: these pass out into the brine and leave the food drier and less susceptible to change, but, deprived of about one-third of its nutritive value, apt to cause scurvy when used too exclusively as a diet, and also less digestible. Small quantities of certain stronger antiseptics enable the original qualities to be in great part retained, and prevent decay for a

[1] The International Congress of Hygiene, 1903, agreed on a minimum of 85° C. for "Pasteurization," but this had main reference to tubercle bacilli.

considerable period with less influence on digestion than the old curing processes. Meat has been preserved with moderate success in an atmosphere of carbonic acid. Joints are often injected in the cavities with preservative solutions, usually boric acid, to wash out serous liquid and leave a small quantity of the antiseptic. Most acids are more or less inimical to bacteria and therefore inhibit putrefaction ; the value of acetic acid for this purpose is familiar, and *formic acid*, which has about three times the power, could probably replace acetic in most of its uses. *Sulphurous acid* for foods is not satisfactory, but is much used for preventing decay in casks, for finings, and by butchers. *Salicylic acid* has been frequently employed in fruit preparations, but is prohibited in many countries. *Sodium benzoate* in 0·1 % strength is probably safer. *Fluorine compounds* in about the same proportion are sometimes used on the Continent in brewing. But the most popular antiseptics are *boric acid* for cream, butter, bacon, fish and milk, and *formaldehyde*, chiefly for the latter. The writer has shown that 1 in 2,000 of boric acid, or 1 in 50,000 of formaldehyde, is capable of keeping milk sweet for twenty-four hours even in warm weather, and neither is injurious in these proportions. Many aromatic bodies are antiseptic, but are not admissible in food on account of their taste or other properties. Total prohibition of chemical preservatives as sometimes advocated is illogical in view of the fact that salt, nitre, and vinegar, which can all be poisonous and are not the most effective antiseptics, are used in such quantities without question. An English Departmental Committee published their investigation of the subject in 1901, and recommended that formaldehyde be prohibited, that no preservative whatever should be allowed in milk, that the only preservative lawful in cream be boric acid in amount not exceeding 0·25 % and in butter and margarine an amount not exceeding 0·5 %; that as to salicylic acid not more may be used in foods than 1 grain per pint of liquid, or per pound of solid, its presence in all cases to be declared ; finally that in dietetic preparations for infants and invalids all chemical preservatives be prohibited (special supply for this purpose is in many cases practised at present). They concluded that preserving agents were needed, that the nature and amount should be declared on the label, and that a Court of Reference should be appointed to prescribe standards and for questions arising; but the subjects are still awaiting legislation.

Another important application of antiseptics is to wood and cordage, in suppressing destructive fungi and insects. The simple tarring sufficient for cordage does not penetrate the interior of wood, so that in the latter case a preservative liquid is made by pressure to enter the vessels. Copper sulphate (Kyanizing) was the earliest agent used, and is still found effective. Creosote oils are now commonly employed, but have the disadvantage of increasing the inflammability. S. R.

Aqueducts.—Artificial water-ways constructed for the conveyance of water through long distances, mostly for purposes of public supply. (*See* "WATER SUPPLY.")

Artizans' Dwellings.—The term "Artizans' dwellings" is generally restricted to dwellings constructed for the accommodation of the working classes by a public company or association, or by a local authority or other public body, or a philanthropist, or group of philanthropists. They form but a small proportion of working class dwellings, for whereas there were in 1901 about eight million inhabited houses in the United Kingdom occupied hy about nine million families, of which it may be assumed seven million were of the working class, the total number of families accommodated in artizans' dwellings coming within the foregoing definition is less than a quarter of a million. Until recently it was the common practice to construct most of these dwellings on the flat system in blocks, but there has latterly been a reversion to the

cottage and other types of small houses. The dwellings erected are now of five types:—

1. Common lodging-houses, with either bunks or cubicles, and large common rooms.

2. Block dwellings, four or five storeys high.

3. Tenement houses of three storeys.

4. Cottage flats in two-storey self-contained dwellings.

5. Cottages of various sizes, self-contained, with gardens.

Among the principal agencies for the erection of lodging-houses may be included Rowton Houses, Limited, a society which has built six "hotels for working men," providing 5,162 cubicles, and having in each house a dining-room, reading-room, and sundry workshops and offices for common use, at an inclusive cost of £400,000 and an inclusive rent of 7*d.* per day which has enabled a gross profit of £15,000 per annum to be made, sufficient to pay over 5 % on the capital.

The artizans' dwellings societies or companies in London have built dwellings, mostly in blocks, for 125,000 persons, and throughout the country 420 co-operative societies have built 48,000 houses, mostly cottages, at a cost of £10,000,000.

Co-partnership housing societies, which are growing very rapidly, have for their basis four main principles: first, that the tenants should hold shares in a society which owns the houses; second, that they should share in all profits made by the estate; third, that land should be bought in bulk and developed with open spaces and a limited number of houses per acre; fourth, that the spirit of fellowship and community should be fostered by the formation of societies of various kinds, and the provision of rooms and institutions for common use. They have a capital of over £1,000,000 and have developed estates at Birmingham, Ealing, Hampstead, Letchworth Garden City, Sevenoaks, Manchester and elsewhere.

Municipalities have been entrusted with important powers and duties with respect to the supervision, improvement and provision of artizans' dwellings by means of no less than 28 Acts of Parliament, of which the chief are:—

(1) The Public Health Act, 1875 (sanitary clauses), together with the amending or corresponding measures, the Public Health Acts (Amendment) Acts, 1890 and 1907, the Public Health (London) Act, 1891, and the Public Health (Scotland) Act, 1897; and bye-laws made under the provisions of the same;

(2) The Housing of the Working-Classes Act, 1890, with amending Acts of 1893, 1894, 1896, 1900 and 1903, which consolidate a number of previous enactments, known as Artizans' Dwellings Acts;

(3) The Small Dwellings Acquisition Act, 1899;

(4) The Municipal Corporations Act, 1882 (Sect. 111), and the Working Classes' Dwellings Act, 1890;

(5) The Labourers' (Ireland) Acts, 1885 to 1906;

(6) The Standing Orders of Parliament for Local Improvement and Public Companies Bills.

So far as the provision of houses is concerned, the most important of these are the Housing of the Working Classes Acts, 1890–1903.

Part I. of the Act of 1890 enables urban authorities to condemn, clear and re-plan insanitary areas and to construct dwellings to re-house the working classes displaced. Over £8,000,000 has been spent under this and preceding Acts on clearance schemes, at a cost of £50 to £70 for each person displaced, in addition to an outlay, partly or wholly remunerative, of £50 to £70 per head for dwellings in which to re-house the dispossessed. The principal schemes have been in London, Glasgow, Liverpool, Manchester, Leeds and Birmingham, but there have been schemes at Bath, Birkenhead, Bolton, Bradford, Brighton, Coventry, Devonport, Dublin, Leigh, Plymouth, Prescot, Portsmouth, Salford, Sheffield, Southampton, Stretford, Sunderland and Wigan. Part II. of the Act provides for (1) the closing

and demolition by urban and rural local authorities of houses unfit for human habitation; (2) the removal of buildings which obstruct light and air; (3) the clearance and reconstruction of small unhealthy areas. It is estimated that there are over 700,000 houses which ought to be dealt with by these provisions, but the average number dealt with annually under all three heads is less than 10,000, and the amount spent on schemes for clearing small areas from 1890 to 1907 was only about £150,000. Part III. as amended by subsequent Acts enables local authorities to acquire land, borrow money, and purchase, or build and let artizans' dwellings furnished or unfurnished of any kind. It also enables them to lease land to companies and private individuals for the construction of such dwellings. It was an "adoptive" Act, but the new Act of 1909 makes it compulsory everywhere. Land may be compulsorily acquired at its "fair market value" which in default of agreement has to be determined by a single arbitrator appointed by the Local Government Board.

Money may be borrowed by local authorities either in the ordinary way by mortgage or by the issue of stock, or it may be obtained at rates varying with the movements of the money market from 3 to 4 per cent. from the Public Works Loan Commissioners. It has to be repaid within periods not exceeding 80 years for the land, and 60 years for the buildings. The total amount borrowed under Part III. amounts to about £2,750,000 of which over £2,000,000 is in respect of provincial towns. Part III. has been "adopted" by the London County Council, 12 metropolitan borough councils, 30 county boroughs, 45 town councils, 50 urban district councils, and 12 rural district councils, or a total of 149 councils. Altogether the municipalities in Great Britain have built about 22,000 dwellings with 60,000 rooms. These include 30 model lodging houses in Glasgow, London, Belfast, Aberdeen, Manchester, Salford, Southampton, Blackburn, Bury, Paisley, and Perth, constructed at a cost of from £40 to £60 per inmate, or an average of £65 per head for building and furnishing, and let at charges of from 4*d.* to 7*d.* or an average of 6*d.* per night inclusive. Municipal block dwellings to the number of 12,500 with over 30,000 rooms have been constructed in London, Dublin, Edinburgh, Glasgow, Douglas, Liverpool, Manchester, Nottingham and Sheffield. The cost of building varies from £70 to £140 per room, but in most cases is between £85 and £100 per room; the rents per room average in London (per room) 3*s.* 1*d.* per week, Scotland and the provinces 2*s.* 3*d.* per week. Most of the dwellings consist of two or three rooms.

Municipal tenement houses to the number of 2,800 with 6,800 rooms have been built in Liverpool, Manchester, Sheffield, Plymouth and Devonport. The cost of building averages £70 per room; rents average 1*s.* 10*d.* per room per week. Most of the dwellings are of two or three rooms.

Municipal cottage flats to the number of about 2,200 with 6,000 rooms have been built in Battersea, Dublin, East Ham, and West Ham. The cost of building varies from £40 to £80 and averages £70 per room; the rent averages 2*s.* 3*d.* per room per week, and the dwellings are about evenly divided between two, three, and four rooms.

Municipal cottages to the number of 4,500 with 20,000 rooms have been built in 75 towns and villages, among which the most interesting schemes are those at Sheffield, Richmond, Merthyr Tydfil, Sevenoaks, Hornsey, and the cheapest are in Altrincham, Bangor, Exeter, Guildford, Neath, Prescot and Stretford. The cost of building has varied from £30 to £80, or an average of £45 per room. About half the cottages cost under £200 each and the other half over £200 each. Rents vary from 4*s.* to 8*s.* per week and average about 1*s.* 6*d.* per room per week. Half the cottages are let at 6*s.* to 7*s.* per week and two-thirds are under 7*s.* per week. Most of the cottages contain four or five rooms with a scullery.

In considering the relative costs of the various types of artizans' dwellings there are

three points to bear in mind: (1) The cost of site, which varies from £1 10*s.* per room for cottages on the outskirts of towns to £120 per room for block dwellings in the centre of large cities. (2) The cost of development of the site by constructing the necessary roads, sewers and approaches, which varies from £4 10*s.* per cottage, or £100 per acre, to £45 per cottage, or £1,000 per acre, according to the nature of the works required by the bye-laws or by the specifications. Under present conditions the cost of development of building sites for cottages is generally between £200 and £500 per acre in urban districts, so that it is often a more important consideration than the cost of the site itself. (*See* "Town Planning.") (3) Cost of building which depends partly upon the varying cost of labour in different districts but also upon the type of house constructed. It will be seen from previous figures that block dwellings cost twice as much per room to build as cottages. Much depends also upon the plans and specifications.

In recent years great efforts have been made by means of local cottage exhibitions to encourage improved methods of design and construction for working class dwellings. At Letchworth Garden City a cheap cottage exhibition was held in 1905, when 85 cottages were erected for competition, at a supposed cost not exceeding £150 per cottage. A second exhibition in 1907 comprised 52 cottages as follows:—Class A: Three rooms and scullery, £175; Class B, four rooms and kitchen-scullery, £200; Class C, five rooms and scullery, £240.

Cottage exhibitions on municipal land have since been held as follows:—

Sheffield, 1907. Forty-two cottages in three classes varying from £175 to £225, all of which were purchased by the Corporation for the sum of £8,391, and are now let to workmen.

Newcastle, 1908. Eighty cottages built under the city bye-laws on municipal land, and varying in cost from £195 to £350 upon city land leased at 4*d.* per square yard per annum for land covered with buildings and 1*d.* per square yard per annum for garden ground.

Swansea, 1909, in course of arrangement.

In the three last-named cases the planning of the site was a special feature of the exhibition.

Rural Housing in England has hardly been touched by local authorities, only 54 cottages having been built, but the famous Labourers' (Ireland) Acts, 1883 to 1906, have had the most remarkable results in Ireland owing, first, to the power given to working men where cottages are scarce or deficient to make an official representation to the rural district council, which must be acted upon, and, secondly, to cheap money and a Government subsidy. The terms for loans have varied from $2\frac{3}{4}$ to $3\frac{1}{4}$%. The amount borrowed exceeds £3,415,000, and the number of cottages built is over 20,634, divided as follows: Ulster, 1,663; Munster, 10,617; Leinster, 8,018; Connaught, 336. They are let at weekly rents varying from 9*d.* to 1*s.* 6*d.* per week, and their average cost has been about £150. £47,480 was received in rent for the year ending 31st March, 1906; the Government subsidy was £41,610, and the rates contributed £63,000. These sums are just sufficient to pay interest and instalments for repayment of principal amounting to £151,898. The rates are paid by the occupiers. A new Act passed in 1906 provides for loans up to £4,250,000 being advanced by the Irish Land Commission repayable on the annuity system in $68\frac{1}{2}$ years at $3\frac{1}{4}$%, for interest and repayment on principal instead of £4 11*s.* 8*d.* as formerly. The Exchequer grant of £37,000 is to be divided among the districts building or having built cottages at a *pro rata* amount per cottage. In future it is estimated that the cost of Irish labourers' municipal cottages will be paid $\frac{11}{33}$rds. by the Government subsidy, $\frac{16}{33}$rds by the labourer, and $\frac{6}{33}$rds. by the rates.

The financial working of artizans' dwellings is a matter of great importance, so the following figures derived from official returns of various local authorities have

special interest. The buildings included in the returns only represent those as to which complete particulars are available.

	London County Council Completed Schemes.	Eight Metropolitan Boroughs.
Capital outlay	£1,900,000	£393,192
Rents received	120,000	28,451
Rates, Taxes, Water and Insurance	28,000	5,557
Repairs and Maintenance	12,500	3,563
Superintendence and Sundries	8,000	868
Total working expenses ..	48,500	9,988
Net return on outlay ..	3·75%	4·66%

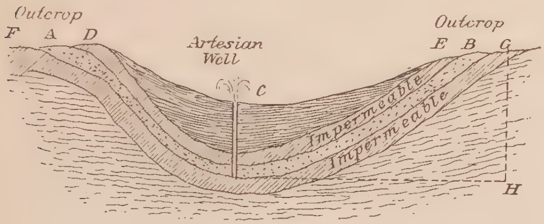
	Forty-five Towns Dwellings Built on Open Land under Part III.	Twenty-two Towns Dwellings Built on Slum Areas or in Central Districts.
Capital outlay	£930,450	£991,246
Rents received	64,631	42,034
Rates, Taxes, and Insurance	17,490	9,046
Repairs and Maintenance	6,472	7,898
Superintendence and Sundries	2,058	2,070
Total working expenses ..	26,010	19,692
Net return on outlay ..	4·14 %	2·25 %

It will be seen from the foregoing that the percentages of rents on capital outlay are: London County Council, 6·3%; metropolitan boroughs, 7·2%; forty-five Part III. schemes, 6·9%; twenty-two re-housing schemes, 4·2%.

The percentages of the rent that go for various expenses are as follows:—*Rates, Taxes and Insurance:* London County Council, 24%; metropolitan boroughs, 20%; forty-five Part III. schemes, 27%; twenty-two re-housing schemes, 22%. *Repairs and maintenance:* London County Council, 10·5%; metropolitan boroughs, 12·5%; forty-five Part III. schemes, 10·1%; twenty-two re-housing schemes, 18·7%. As the rate of interest on loans was in most cases 3 to 3½%, the first three groups appear to be self-supporting, and the last group (dwellings on central or slum sites in provincial towns), shows a deficiency of 1% per annum. It has, however, to be remembered that in the case of the London County Council, as well as some of the metropolitan boroughs and also some of the last group of provincial towns, the site has not always been charged to the capital outlay at its full cost, but in some cases at a figure called the "housing valuation," which represents only the value put upon the sites for housing purposes, and varies from £2,000 to £4,000 per acre. In some cases it is only one-tenth of the actual cost. If the actual cost of clearance of the slum sites be added to the capital outlay, the net return on capital outlay would remain the same for the forty-five Part III. schemes, but would be 1% less for London County Council schemes, and ½% less for the twenty-two provincial re-housing schemes. The real justification for outlay on municipal artizans' dwellings is the saving of life and health which follow improvement schemes. Death rates have fallen 30% in the last seventeen years for London; 3·7 per 1,000 on Plymouth Part I. areas; 10 per 1,000 in Glasgow during forty years; 17 per 1,000 for the Trowgate area; and 35 per 1,000 in respect of slum areas cleared in Liverpool. W. T.

Artesian Well.—An artesian well is a boring into the earth through which water rises. In some cases the water overflows under considerable pressure, at the surface of the earth, due to the natural phenomena of water finding its own level. The name "*Artesian*" is derived from the belief that such wells were first employed in the French province of Artois, but they appear to have been used at a much earlier date in Lombardy, Asia Minor, Persia, China, and Egypt. The principle of the artesian well will be at once apparent from the figure, where it is seen that a *permeable* layer *A B* exists between two *impermeable* layers *D E* and *F G*. Water enters the porous strata at its "outcrop" at *A* and *B*, and accumulates in the bottom of the basin until it becomes fully saturated. Upon boring a well at *C*, the water rises therein under a head *G H*, or other pressure according to the saturation level in the porous strata. The water which supplies artesian wells is some-

times drawn from distances of as much as 60 or 70 miles. A well at Grenelle, in the vicinity of Paris, is about 1,800 ft. deep, and yields about a million gallons per day, the temperature of the water being 80° F. Several artesian wells have been sunk by the writer through about 200 ft. depth of Wadhurst clay and penetrating a further 200 ft. into the Ashdown sands of the Hastings series for public water supply purposes. The artesian rise of the water is about 100 ft. These wells vary in diameter from $11\frac{1}{2}$ in. to about 16 in. and are lined throughout with steel tubes, the bottom lengths being perforated. The water is raised in one case by an "air-lift" and in the other



Permeable layer, *A B*, between two impermeable layers, *D E* and *F G*.

cases by deep-well pumps. Large quantities of water are obtained in a very similar manner in the Colonies for agricultural and other purposes. In Queensland some 200 million gallons daily is obtained from borings, the water in many cases overflowing at the surface under considerable pressure necessitating control by regulating valves. Artesian water is also largely used in New South Wales, and in the Cape of Good Hope, in the United States, Algeria and Sahara and other parts; its discovery in all quarters proving an invaluable and indispensable aid to the development of the respective countries. It should be remembered that water occurring in the chalk and other strata is almost entirely contained in the fissures of the rock, and that borings sunk in districts where such fissures are few and far between are not likely to yield a good supply. W. H. M.

Asphalte.—A native mixture of hydrocarbons, found under varying conditions and differing widely in composition. Its chief use is as an ingredient in numerous paving materials (patent and otherwise); also, in combination with felt, wire meshing, and crushed stone (lime-stone, sand, or granite), for producing waterproof sheeting for damp courses (*q. v.*), in puddling sheets as a protection for underground tanks and ponds, and for providing a dry base for the footings of foundations laid in water-logged soil or ground traversed by freshets; also as a damp excluding insulating material in electrical engineering. For practical purposes asphalte falls into four broad groups: (1) A bituminous mass mixed with clay or marle, as in the deposits of Trinidad, Cuba, and Mexico; (2) bitumen mixed with quartz, as in the deposits of Pyriment-Seyssel, Clermont, &c.; (3) bitumen mixed with schist *débris*, as in the deposits of Autun, Allier, Dauphiné, &c.; (4) bitumen mixed with calcareous *débris*, as in the asphaltes of Seyssel, Val de Travers, Lobsann, Clermont, &c. The character and behaviour of the mass depend largely on the nature of the oily constituents. Oils of the coal tar group are highly volatile; on distillation they appear quite limpid, but quickly discolour, diminish in bulk, and become viscous and hard. Consequently asphaltes containing coal tar oils soon become excessively brittle, dry, and rapidly deteriorate under ordinary wear and even under atmospheric influences. For this reason the many attempts to produce artificial asphaltes by mixing coal tar with limestone have failed. For paving purposes it is necessary that the oil should be non-volatile, and an evaporative test is usually demanded. But this is of less importance when the asphalte is intended as a binder in preparing solid dustless macadam roads; and, therefore, for this latter purpose artificially prepared asphaltes (mixtures of petroleum and carbonate of lime) are admissible. A proposed specification for a macadam binder of 80 per cent. asphalte contents, is as follows: (1) It shall be soluble in bisulphide of carbon to not less than 99·5 per cent.; (2) it shall be soluble in carbon tetrachloride to not less than 99·5 per cent., as a proof that the mixture has not

been overheated, as this would produce carbenes; (3) when heated to a temperature not exceeding 500° F. until 20 per cent. of the mass is evaporated, the residuum shall have a penetration of not more than 10 mm. when tested with a No. 2 needle, weighted with 100 grs. at 77° F., on the Dow machine; (4) the compound shall be sufficiently liquid at working temperature 50 cubic c.m., not to take more than 200 seconds to flow out when tested in an Engler viscosimeter at 212° F.; (5) the solid contents of the material shall consist only of asphalte, and the consistency of the residue shall not be due to any other solid substance, such as paraffin. The paraffin scale of the total compound shall not exceed 1 per cent. The paraffin scale is to be determined by destructive distillation of the entire compound to coke, and determination of the paraffin scale in the distillate; (6) the asphalte binder shall not contain any dirt or water, but shall consist of pure bitumen only. Tar or substances recovered from acid sludge shall not be admitted. For a binding material, he above is a rather drastic specification.

For paving purposes asphalte is placed on the market in three principal forms: (1) Partly purified, made up into flat circular slabs, this is melted in cauldrons with a small percentage of bitumen to act as a flux, sand or gravel usually being added, the mass being poured out on the site to be paved, rolled out and compressed; (2) in the form of powder; (3) rock asphalte—this latter has to be ground cold in a special mill. Both these forms are heated in cauldrons before use, laid while hot, pounded and smoothed with heated irons; (4) patent mixtures, usually in the form of slabs, to be melted down for laying *in situ*, and containing special ingredients, such as cork refuse, &c.

In electrical engineering asphalte is used in a refined state (bitumen) for insulating joint boxes, lining trenches, and impregnating the fibrous outer casing of cables. (*See* "Dust Prevention," "Footpaths," "Roads," and "Streets.")

Asphalte Paving.—(*See* "Roads.")

Bacteria.—Classification and Morphology.—Reproduction.—Products of Bacterial Growth.—Influences affecting Bacteria.—Observation and Staining.—Culture.—Pathogenic Bacteria and their relation to Sanitary Problems.—Diseases due to other Micro-organisms.

Classification and Morphology.—Bacteria are minute unicellular plants devoid of chlorophyll. Bacteriology comprises not only the study of bacteria, but also of other micro-organisms, some of which belong to the animal kingdom. The micro-millimetre (μ), the thousandth part of a millimetre, is the unit by which bacteria are measured. Bacteria vary in size from $0{\cdot}3\mu$ to $5{\cdot}0\mu$; they are classified according to their shapes: a bacillus is rod-like, a coccus is round or spherical, while those spiral in form are known as spirilla. Some spirilla may occur in a shorter form as curved rods, known as "vibriones." The cocci are found grouped in characteristic ways. They may occur in pairs (diplococci), in chains (streptococci), in clusters like a bunch of grapes (staphylococci), and some bacteriologists add a fourth group of cocci — the sarcinæ, which divide in three directions and in two planes. Bacteria are not capable of spontaneous generation; they can only be produced from similar organisms.

Reproduction. — Bacteria reproduce by fission, the mother cell dividing into two organisms. Some species are also capable of reproduction by spores, which are highly refractile bodies, formed either within the cell, or, in some cases, the entire organism becomes converted into a spore. Spores possess a remarkable resistance to physical and chemical agents. Few of the pathogenic bacteria produce spores, but *B. anthracis*, *B. tetani*, *B. Welchii* and *B. botulinus* are sporulating organisms. Organisms deriving nourishment from living tissues are termed *parasites* in contradistinction to *saprophytes* which favour dead material. Most parasites can be cultivated on artificial media—the leprosy bacillus being a notable exception. While some organisms require free oxygen (aërobes), others exist only in its

absence (anaërobes), and some are capable of living under either condition.

PRODUCTS OF BACTERIAL GROWTH. — The action of bacteria is generally of an analytic nature, the complex material in the media being converted into simpler compounds. Surface soil contains large numbers of aërobic bacteria which diminish with depth, few being found below five feet. Even anaërobic bacteria are absent in the lower layers. When brought in contact with the soil bacteria, the proteins, &c., of cadavers and excreta are first converted into liquid peptone-like bodies by organisms of the *proteus* group. A further simplification into organic acids and simpler nitrogenous bodies having occurred, these are converted into ammonium salts by *B. mycoides*, &c. The nitrous bacteria convert the ammonium salts into nitrites (nitrosation), while the nitric organisms oxidise the nitrites into nitrates (nitratation) which are available for plant assimilation. Leguminous plants have nodules on their roots, which contain bacteria capable of absorbing atmospheric nitrogen. Some soil bacteria have the same property. Preparations of such bacteria have a remarkable effect on poor soils. *Ptomines* are produced in flesh foods through bacterial metabolism. The smell accompanying putrefaction is due to gases such as methyl mercaptan, which can be detected by the nose when $\frac{1}{23,000,000}$ of a milligramme is present in a litre of air. The symptoms produced by pathogenic bacteria are mostly due to the production of poisons (*toxins*). If the amount of toxin be insufficient to cause death an *antitoxin* will in many cases be developed in the blood capable of neutralising the toxin. The resistance of the blood can be raised by gradually increasing the dose of toxin until complete immunity is conferred and the blood serum of an immune animal confers the protection on an animal injected with it. Many bacteria produce gas, others form a pigment. The characteristic red colour of *B. prodigiosus* is utilised to ascertain the identity of watercourses running underground for a distance, and is also sowed on the surface soil to see whether any bacteria can gain access to a well by percolation. Yeasts and some bacteria ferment the carbohydrates. In common with certain true bacteria, yeast cells contain unorganised ferments (*enzymes*) which act after extraction from the living organism. Bacteria produce the phosphorescence on mackerel and decaying wood.

INFLUENCES AFFECTING BACTERIA. — The violet and ultra-violet rays of the spectrum have a germicidal effect, the red rays having none. The electric arc has a similar action to sunlight but in a less degree. It is doubtful if sunlight assists to any extent in the purification of water; probably only organisms near the surface are affected to any degree. Bacteria vary in resistance to desiccation, the spores being especially resistant. Cold, while the exposure lasts, inhibits growth but does not kill bacteria. The glass apparatus used in bacteriology is sterilised by exposure to dry heat at 150° C. for at least half an hour. Tubes and flasks containing media are sterilised under pressure in an autoclave or on three successive days in a steam steriliser by an exposure on each occasion of twenty minutes to one hour. This "Fractional Sterilisation" is calculated to allow spores, left alive after the first sterilisation, to develop into the more easily killed bacteria. (*See also* "DISINFECTANTS," and "DISINFECTION.")

OBSERVATION AND STAINING.—Bacteria can be examined with a $\frac{1}{12}$th in. objective, although for the larger bacilli in the fresh condition a $\frac{1}{6}$th in. is sufficient. A drop of liquid containing them is placed on a sterile microscope slide by means of an inoculating needle,[1] a clean coverslip is superimposed and the microscope focussed, using cedar wood oil if the objective be an "oil immersion." Under the microscope bacteria appear as pale translucent

[1] An inoculating needle is a piece of platinum wire fused into a glass rod. For liquids the free end of the wire is bent into a loop two or three millimetres in diameter. Before and after use this needle and such part of the rod as may have become contaminated is sterilised by heating in a Bunsen flame.

bodies, some being capable of motion. Apparently they contain no nucleus. Some bacilli and spirilla have whip-like threads of protoplasm (flagella) which render them motile. Bacteria are readily stained with anilin dyes, anilin, phenol, &c., being used as mordants. A droplet of water is placed on a clean coverglass, and by means of an inoculating needle some of the material to be examined is added, mixed with the water, spread evenly over the coverglass and allowed to dry. The preparation is "fixed" by passing the coverglass, held by forceps, three times through the Bunsen flame at the rate of the swing of an ordinary clock pendulum. A solution of a stain is added and allowed to act for a suitable time, when it is drained off and the coverglass washed in water to remove superfluous stain when it is again allowed to dry. A drop of a mixture of Canada balsam and xylol is placed on a microscope slide and the cover-glass gently pressed thereon—prepared side downwards—and examined with an oil immersion lens.

Culture.—The cultivation of bacteria on artificial media serves two main purposes: it allows the separation of various organisms (in practice a pure culture of a single organism is rarely encountered) and the manner of growth on different media is invaluable for the identification of the organisms. A medium constantly used is a nutrient broth, made from extract of meat, peptone, and salt. This is too acid and is made neutral to phenol-phthalein, and then 10 cubic centimetres of normal hydrochloric acid are added to each litre of the neutral broth (a reaction of $+ 10$ on Eyre's scale). This reaction is acid to phenol-phthalein but alkaline to litmus—a suitable reaction for most organisms. (*See also* "Bacteriology of Water" and "Bacteriological Examination of Disinfectants.") Milk and many other liquids are also used. The solid media are also very numerous — solidified blood serum and ascitic fluid, potato and various jellies are used; two of these jellies are made by adding to the nutrient broth, above described, either 10 per cent. of gelatine or $1\frac{1}{2}$ per cent. of agar. The former is used for temperatures about 22° C., and the latter for blood-heat cultures. Gelatine and agar media are used for the isolation of various organisms — some of the material to be examined being mixed with the liquefied media, which, after being poured into covered glass dishes (Petri dishes), is allowed to set. The individual bacilli are now isolated and on incubation each produces a colony of its own species which can be submitted to examination and sub-cultured.

The Relation of Pathogenic Bacteria to Sanitary Problems. — The *fons et origo* of sanitary science is the prevention of the spread of pathogenic bacteria, and although this idea may be wrapped up in a mass of engineering problems, the principle is still fundamental. It is therefore necessary to appreciate the various ways in which infection can be carried and the means at our disposal for preventing or limiting the same. Bacteria were at one time considered to be chiefly air-borne, but with the probable exception of small-pox, it is seldom that infection is so transmitted. Bacteria certainly occur in the air, being carried on fine particles of dust; but even in sporadic outbreaks of disease other channels of infection can usually be identified. The presence of damp surfaces in preventing the rise of "dust rafts" of bacteria, conduces to the reduction of the air bacteria. The emanations of sewers have been considered a predisposing cause of typhoid, diphtheria, and tonsilitis. Andrews and Horrocks have proved that sewer gas contains sewage bacteria and thus may not only lower the resistance of the body to disease, but may also convey the specific bacteria. Bacterial sewage systems depend on the solvent and liquefying action of the sewage bacteria on the solids (*see* "Sewage Disposal"). In the filtration of water through sand, an unsatisfactory filtrate is obtained until a slimy deposit of bacteria and algæ has formed on the filter bed, when a reduction of 99 per cent. of the organisms can be attained.

The typhoid bacillus (*B. typhosus*) occurs in the eruption, sweat, sputum, urine and stools of enteric patients. The urine and fæces by gaining access to a water supply may cause infection. The typhoid bacillus gradually dies out when introduced into water, but it appears from recent experiments by Houston that although 99·9 per cent. of the typhoid bacilli disappeared within the first week, a period of nine weeks was necessary for its total disappearance. Hence the desirability of storing water obtained from sources not above suspicion. The typhoid bacillus will live longer in sterilised than in unsterilised water and when inoculated into unsterilised water, containing little organic matter, survives longer than when the organic matter is considerable. Flies feeding on the dejecta of typhoid patients take up the organism and thus spread the disease. Shell-fish and water-cress obtained from polluted waters are prone to infection. The typhoid bacillus may remain latent in the body for many years without its presence being suspected and without the host giving any indications of the disease. The "typhoid carrier" through the discharge of infected fæces may thus unwittingly cause serious outbreaks of the disease. Apparently about 3 to 4 per cent. of typhoid convalescents become chronic "carriers" while still more are temporary "carriers" for 2 or 3 months. Although soil in this country may become polluted with typhoid, its capability of conveying the disease is more restricted than in hot countries. In India excreta are buried in the ground, and during the frequent dust storms are carried with the dust for long distances. Virgin sandy soil and peat are inimical to the growth of the typhoid bacillus and it lives longer in moist soils than in dry. It rapidly dies in a cultivated soil, owing to the antagonistic action of the other bacteria. Typhoid can be conveyed by fabrics, soiled blankets, &c., producing cases through subsequent use. It is generally agreed that the clinical phenomena, known as "typhoid fever" are not necessarily due to the *B. typhosus*, other organisms of the typhoid-coli group producing it. The group of organisms classed as "dysentery bacilli" are found in the stools of epidemic dysentery and infantile summer diarrhœa. There is no record of them being found in water.

B. coli communis is a normal inhabitant of the colon of man and the lower animals. It has also been found in the intestines of carrion birds and of some fish. Apart from its pyogenic and other pathological qualities, it is of interest as an indicator of fæcal contamination of water, milk, shell-fish, &c. While in some respects resembling the typhoid bacillus, it shows certain marked morphological and cultural differences. It has three or four flagella and is feebly motile, *B. typhosus* being actively motile and possessing eight to twelve flagella.

The *Spirillum choleræ Asiaticæ*, or the "Comma Bacillus," is the specific organism of cholera. (Chicken cholera and hog cholera are due to totally different organisms.) It is found in the "rice water" stools and vomit of cholera patients, and may be conveyed by water, milk, uncooked vegetables, flies and fomites. Cholera spreads most rapidly when the earth temperature is high; this is generally coincident with low ground water. Pettenkofer observes that an increase in cholera is often preceded by a fall in the ground water. In water, the cholera spirillum rapidly dies out, but while present is most likely to be found on the surface.

B. anthracis, the organism of "wool sorters' disease" and "malignant pustule," forms highly resistant spores. It has been found in a catch-pit in a hide factory, in sewage and tannery effluents, in Yeo mud, and in feeding stuffs. It chiefly enters this country on Persian wool, Chinese hides, and Russian hair, the blood stains and not the dust being probably the actual carriers of the germs. The spores in the bloody discharges not only make anthrax endemic in the vicinity but are probably also distributed by wind and flood. Earthworms have been said to carry the spores from buried carcases to the surface,

but this is questioned. "Rag sorters'" disease is due to another bacillus. (Shoddy is prepared by the disintegration of disused garments and other cloth likely to be contaminated with bacteria, which are mixed with some new wool and freshly woven. Such disused garments are also made into "flock" for stuffing mattresses. As the old material is very seldom disinfected in any way, and is of a nature that favours the retention of bacteria, its use is attended with danger, and legislation on this point is strongly needed.)

B. tuberculosis may affect the lungs, peritoneum, the membranes surrounding the brain, the skin, bones, and lymphatic glands, producing the various manifestations of tuberculosis. Like the leprosy and smegma bacilli, it is "acid-fast," *i.e.*, when stained with hot carbol-fuchsin, the colour is not easily removed by 25% sulphuric acid. Certain bacteria occurring in butter and fodder have the same property, and hence the presence of an acid-fast organism in milk or butter offers only presumptive evidence of tubercle. The cow suffers from tuberculosis, which, when affecting the udder, infects the milk. The bovine tubercle bacillus is generally supposed to be identical with the human bacillus, and when present in milk is held responsible for abdominal tuberculosis. The flesh may also contain this organism, and the cooking is often insufficient to destroy it. Birds also suffer from the disease, and although the avian bacillus possesses slightly different characters, organisms with the characters of the avian bacilli have been isolated from the human subject. The tubercle bacillus abounds in phthisical sputum, and it is by inhalation of either dried expectoration or the wet spray expelled when a patient coughs, that the disease is chiefly conveyed. It is also conveyed by flies, and on the bodies, particularly the lips and hands, of patients. The dust in railway carriages, public-houses, and the homes of patients, is often the cause of infection. Operatives in trades in which particles of dust are produced, are very liable to the disease. The compulsory segregation of infected persons being impossible, recourse must be had to the prohibition of promiscuous expectoration, a judicious use of disinfectants, and proscription of infected food to reduce the disease; while the resistance of the body is materially increased by improved ventilation and general sanitary conditions, prevention of overcrowding, better feeding, and alleviation of social misery.

B. diphtheriæ occurs in the throats of persons suffering from diphtheria, and forms toxins which are carried by the circulatory system. It is also occasionally found in throats of healthy persons. The disease is more prevalent in temperate than in tropical climates and is conveyed chiefly by personal contact, although epidemics have been traced to milk, while it is possible that the bacteria are also carried by the dust and wind. Sewer emanations predispose to the disease. An organism simulating the true diphtheria bacillus is sometimes met with (Hoffman's bacillus).

Streptococci occur in puerperal fever, scarlet fever, sore throat, meningitis, &c. Diplococci occur in pneumonia and gonorrhœa. These strepococci and diplococci are pyogenic, as also are the staphylococci found in a variety of affections.

Tetanus is caused by the introduction into a wound of the *B. tetani*, which occurs in soil and manure. It forms spores which, when stained, give the appearance of drumsticks. Influenza is due to a bacillus. It may perhaps affect dogs and cats, and "pink eye" in horses is probably due to the same bacillus. *B. mallei* produces glanders and farcy, and chiefly affects horses, asses, and mules. Through being bitten, or otherwise receiving the equine mucus or saliva, man may be infected and also probably by eating the raw flesh of an infected animal. In man, glanders and farcy generally occur together instead of separately as in the horse. Knackers, however, possess a remarkable immunity to glanders. Actinomycosis (ray fungus) is a streptothrix — one of the higher forms of bacteria. In cattle it produces "lumpy jaw"

and "wooden tongue" and is communicable to man. It is epiphytic on cereals and straw, which probably communicate it to animals. Madura disease in its black variety is due to a streptothrix.

Quarter-evil, foot and mouth disease, and swine fever are also due to micro-organisms.

Diseases due to other Micro-organisms.—Malaria is caused by a protozoan parasite, the *Plasmodium malariæ*. It is conveyed by mosquitoes belonging to the Anophelinæ. In the body of the insect and in the blood of the host, it goes through a long cycle of changes. Prophylactic measures deal chiefly with the exclusion of mosquitoes and the destruction of their larvæ, which are deposited in stagnant pools, by draining and covering the surface of the pools with petroleum or insoluble tar oils. Sleeping sickness is considered to be caused by *Trypanosoma gambiense*, a protozoan organism carried by a tsetse fly. A trypanosome (*Tr. Brucei*) is found in nagana (tsetse fly disease of horses) and another in Surra. A trypanosome is a spindle-shaped organism, with an undulating membrane at the side and an anterior flagellum. Tropical dysentery is due to amœbæ. Infection takes place from water and green vegetables. The hyphomycetes are generally non-pathogenic, but *Aspergillus niger*, the ringworm fungi, and *Oidium albicans* are pathogenic, the latter causing the white patches occurring in the mouths of infants suffering from thrush. Syphilis is attributed to a spirochæta (a spiral filiform parasite with no flagella, but having an undulating movement) known as *Treponema pallidum*. The ætiology of carcinoma, sarcoma, hydrophobia, and small-pox is uncertain, but probably the last two are caused by protozoa. There is sufficient evidence to warrant an assumption that damp houses are a factor in the production of cancer. It is possible that the infective agent (if such there be) exists in uncooked fruit and vegetables. Acari and microscopic eels may also have something to do with the infection.

W. P.

Bacteria Beds.—(*See* "Sewage Disposal.")

Bacteriological Examination of Disinfectants. — **Influences affecting Germicidal Value — The Carbolic Acid Coefficient — The Garnet Method — The Thread Method — The Rideal-Walker or Drop Method—The Influence of Organic Matter — The Sommerville-Walker Coefficient.**—As the function of a disinfectant is to kill micro-organisms, it is obvious that the proof of such capability by laboratory experiments indicates its value in a way that chemical analysis never can. In the case of some coal tar disinfectants chemical analysis is absolutely useless as a measurer of germicidal power, this being to a large extent dependent on physical conditions not indicated by chemistry. In practice bacteria are met with in conditions of varying vitality and environment. Some of these conditions cannot be properly simulated in a laboratory test, but by the introduction of various forms of organic matter we are able to ascertain with a reasonable degree of accuracy what conditions will diminish the value of the disinfectant. It is first necessary to ascertain the action of the disinfectant on "naked" bacteria, *i.e.*, bacteria unprotected by any large quantity of organic matter, and then to incorporate in the test organic matter likely to be met with in practice, and find if any depreciation has occurred.

The statements often seen to the effect that a certain disinfectant when used in a particular dilution will kill a certain organism in a specified time may be regarded as fallacious. Such tests are performed by adding to the diluted disinfectant a few drops of a bacterial culture, and at the end of certain periods transferring a loopful of the contaminated disinfectant to a tube of sterile broth, labelling, and incubating. A growth (which gives the broth a turbid appearance) shows that when the "sub-culture" was made from the contaminated disinfectant the bacteria were still alive. If death had occurred no growth would have taken place in the "sub-culture," and the broth would have remained clear. Such

results are worthless for the following reasons: Even bacteria of the same species do not possess an identical resistance to disinfection. The number of organisms that will be killed by a given quantity of disinfectant is limited, and the velocity of disinfection also depends on their resistancy or age. When first brought in contact with the disinfectant the mortality of the bacteria is large but gradually becomes slower, and when a curve is plotted with the numbers of surviving bacteria as ordinates and the corresponding times as abscissæ, it is hyperbolic in form. The temperature of the disinfectant during the period of contact (the medication temperature) affects the result considerably, a rise of two or three degrees, especially above the optimum temperature for the growth of the organism, very appreciably increasing the power of the disinfectant. Similarly a culture which has been incubated at a temperature favourable to the growth will be more resistant than one grown at a less satisfactory temperature. The same remark applies to the reaction and constituents of the culture medium.

The Carbolic Acid Coefficient. — In 1896 Moor suggested, in order to obtain some trustworthy datum of the germicidal value of a disinfectant, that at the same time as it was tested, a solution of some trustworthy disinfectant should also be tested under the same conditions. This allows a comparison between them. Carbolic acid (phenol) is the standard disinfectant usually selected for this purpose as it can be accurately standardised. (Mercuric chloride is less satisfactory and its antiseptic effect in the sub-cultures is so marked that it is necessary to add to the sub-culture tubes some sulphuretted hydrogen water to convert it into an inactive sulphide.) Such an expression of germicidal activity is known as "the carbolic acid coefficient." As will be seen when considering the Rideal-Walker test, this method provides for the simultaneous examination of a standard carbolic acid solution, and when a strength of the disinfectant under examination is found to kill the test organism in the same time and *at* the same time as the control carbolic acid, it is evident that the two strengths allow of comparison. Thus should a 1 in 250 solution of a disinfectant X allow of growth up to 5 minutes and kill in $7\frac{1}{2}$ minutes, and a 1 in 100 solution of phenol give life and death in the same periods, the carbolic acid coefficient of X would be $\frac{250}{100} = 2{\cdot}5$. Reference to a chart of a test given later will further explain this. Carbolic acid coefficients obtained by different methods often differ, and workers not adhering strictly to the *modus operandi* with the same test also obtain unsatisfactory results. Hence when the precise technique of the Rideal-Walker test has been followed, it is customary to specify the same by calling the carbolic acid coefficient so obtained the *Rideal-Walker Coefficient.*

As tests on naked germs, three methods have been put forward: the Garnet, Thread, and Rideal-Walker methods.

The Garnet Method.—In this test, devised by Kronig and Paul, the culture of the test organism is dried on garnets the size of a pea. The garnets with the covering of the test organism are soaked in solutions of the disinfectant for known periods of time, when they are removed, well washed with sterile water, and then dropped into broth tubes. A carbolic acid control is introduced, but the test is very liable to error since the organism as well as the disinfectant may be removed in the washing.

The Thread Method.—An emulsion of an agar culture in sterile water is made, and sterilised silk threads are soaked in the filtered emulsion for an hour and then dried. Four dilutions of the disinfectant and one of the control are placed in thirty water watch glasses, each dilution being put into six watch glasses. An infected thread is placed in each watch glass, and from each different dilution an infected thread is taken at the end of every $2\frac{1}{2}$ consecutive minutes up to 15 minutes, well washed with sterile water and placed in a broth sub-culture tube. The difficulty of washing away the disinfectant without removing the organism renders the results very

unsatisfactory, and, like the Garnet method, it is eminently unfitted for working with organisms at all sensitive to desiccation.

The Rideal-Walker Method (The Drop Method).—This test has been adopted by most bacteriologists, disinfectant manufacturers, and large users of disinfectants, as a standard method, the process being undoubtedly the most satisfactory hitherto devised. A special test-tube rack is desirable, having two tiers, the upper for six sets of five tubes for sub-cultures and the lower tier with five holes for four medication tubes of the disinfectant and one of the control. The broth tubes in the upper tier are numbered from 1 to 30. The test is usually performed on a broth culture of the typhoid bacillus, which after inoculation has been incubated for 24 hours at blood heat. Other organisms may also be used, and it should be here remarked that disinfectants show a marked selective action on bacteria, the latter being more sensitive to one disinfectant than to another when both disinfectants may have an equal effect on bacteria of another species.

The inoculating needle has a loop of 3mm. diameter, the centre part of the loop being bent down. The standard carbolic acid is best kept as a 5% solution, which has been standardised by the bromine method. The requisite dilutions for controls are made from this.

The broth recommended by Rideal and Walker for cultures and sub-cultures has the following composition:

Lemco . .	20 grammes
Peptone (Witte) .	20 grammes
Salt . . .	10 grammes
Distilled water to 1 litre.	

It is directed to boil the mixture for 30 minutes, filter, neutralise with normal sodium hydrate solution, using phenolphthalein as an indicator, and when neutral, to add 15 c.c. of normal hydrochloric acid. This gives an acid reaction of + 1·5 per cent. (+ 15 Eyre's scale). The broth culture used should be free from clumps. This may be attained by running the culture through a sterile filter paper, or, as will be found more convenient, after agitation of the tube, allowing it to stand for 20 minutes before use, when the clumps will settle to the bottom and need not be disturbed when pipetting the culture into medication tubes. As the number and, consequently, the resistance of the organism probably differs according to the method adopted for the removal of the clumps, one process should be adhered to so that the culture will not vary much from day to day. All pipettes, measures, and test-tubes must be sterile.

The temperature of the room should be noted and the strength of carbolic acid used as a control altered to suit. (When working with an organism of unknown strength a "phenol table" should be made in which five strengths of phenol are tested in the same way as when a disinfectant is the subject of the test. Then a strength should be selected which gives "life" at $2\frac{1}{2}$ and 5 minutes and "death" at $7\frac{1}{2}$, 10, $12\frac{1}{2}$, and 15 minutes.) Five sterile test-tubes, plugged with cotton wool, are placed in the lower tier of the test-tube rack. Three c.c. of four dilutions of the disinfectant (made with distilled water) are put into the first four and the same amount of the control in the fifth. Into each in succession, at intervals of 30 seconds, three drops of typhoid culture are pipetted, the tubes being agitated to disperse the bacteria through the disinfectant. Half a minute after the fifth inoculation, a loopful is taken from the first medication tube and placed in the broth tube marked "1." This process is repeated at intervals of 30 seconds with the other medication tubes until the first five sub-culture tubes have been inseminated. (These will subsequently show whether an exposure to disinfectant of $2\frac{1}{2}$ minutes has been sufficient to kill the organism.) At the time when the first sub-culture from the fifth medication tube is made, the organism in the first tube will have been exposed for $4\frac{1}{2}$ minutes and 30 seconds later this is inoculated into broth tube "6," and so on until all the sub-culture tubes have been inoculated. As the tubes are inoculated they are placed in a wire basket

and are subsequently incubated for three days at 37° C. They are then replaced in the test-tube rack and the results observed and charted. The results of an actual test are given below:

B. Typhosus, 24 Hours' Broth Culture at 37° C.

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
X . .	1·120	−	−	−	−	−	−	72 hours	37° C.
X . .	1·240	+	+	−	−	−	−	"	"
X . .	1·360	+	+	+	+	−	−	"	"
X . .	1·480	+	+	+	+	+	+	"	"
Carbolic Acid	1·120	+	+	−	−	−	−	"	"

$\therefore$ Rideal-Walker Coefficient $\frac{240}{120} = 2{\cdot}0$.

+ = growth in sub-culture (life); − = no growth in sub-culture (death).

Certain disinfectants when diluted separate out into layers, having very varied germicidal powers. As such disinfectants if made up a day or so before use are liable to produce a false sense of safety, the authors of the Rideal-Walker test have requested that a 1% solution of the disinfectant under examination should be made up 24 hours before testing, and the further dilutions made from this.

The results obtained by the Rideal-Walker process only show the value of a disinfectant when possible militating organic matter is practically absent. It has served and still serves the very useful purpose of eliminating disinfectants which are practically devoid of germicidal power. But it does not exclude the hypochlorites, permanganates and other disinfectants dependent for their germicidal powers on an oxidising action, which action is preferentially expended on dead matter rather than on bacteria. Various forms of organic matter have been suggested for incorporation in the test. Hewlett and Kenwood used fæces and the Lister Institute also recommend a 3% emulsion of dried and ground fæces for the purpose. This excretion varies so enormously in composition that its introduction into a standard test causes hopelessly erratic results, and the plea that it represents animal matter requiring to be disinfected in practice is put out of court owing to the impossibility of disinfecting stools by chemical means alone; moreover the fæces as used in the test bear no resemblance to the article met with in practice. Milk has also been suggested as a suitable material, but the fat globules exercise a protective influence over the bacteria in a way that no other material likely to require disinfection does. Urine on the other hand has constantly to be disinfected, and its incorporation in the test as a diluent in the place of distilled water serves to bring down the "false coefficients" of the oxidising disinfectants.

Sommerville and Walker have emphasised the necessity of using separately certain simple organic substances. They first of all dilute the disinfectant with water, in the proportion recommended by the manufacturers, and make the further dilutions with 1% solutions of blood serum, mucin, peptone, casein, gelatine, blood, or with whole urine. The disinfectant is then allowed to remain in contact with the organic matter for one hour before adding the test organism. This in some degree simulates the conditions met with in practice where a disinfectant, soon exhausted on organic matter, offers no further opposition to further additions of infected material. In

the case of the oxidising disinfectants the germicidal power wasted on the organic matter is obviously lost, but when a lowering of the coefficient occurs with the coal-tar disinfectants, it is thought by some observers that this does not necessarily indicate a depreciation of the disinfectant. It is possible that the disinfectant carried down by sputum or other organic matter, may still be capable of continued action. To meet the influence of absorption, Sommerville and Walker have introduced particulate matter in the form of granules of rice starch. The diluent consists of water and animal and vegetable matter consisting of 0·5 % of gelatine, in solution, and 0·5 % of rice starch (in suspension). Results obtained with this diluent are known as the *Sommerville-Walker coefficients.*

In all forms of disinfection, Defries's "factor of safety" must be recognised. Sommerville and Walker suggest that "it might be insisted that the multiple 5 be applied as a minimum to the strengths of the various disinfectants which are found to perform the same work as 1 in 100 phenol." W. P.

Bacteriology of the London Water Supply.—**Sources—Districts—Works—Results (raw waters, stored waters, filtered waters, number of bacteria, B. coli test, type of B. coli &c., remarks)—Research Work—Reports—Summary and Conclusions.**

1. Sources.—The sources of the Water Board's supply are from (1) the River Thames (about 52%); (2) the River Lea (about 23 %); and wells and springs (about 25 %).

2. Districts.—The administrative districts of supply are as follows:—Eastern, Kent, New River, Southern and Western (total population, nearly seven millions).

3. Works.—From the point of view of *quality* of water, the Water Board's supply is best considered as the following separate waterworks:—

(1) East London (Clapton, Lea Bridge) filtration works (*i.e.*, Lea water mixed with some well-water, after prolonged storage in the Walthamstow reservoirs; also some well-water).

(2) Sunbury (Hanworth) filtration works (*i.e.*, River Thames water after settlement and passing through roughing filters; also gravel or spring water).

(3) Kempton Park filtration works (*i.e.*, chiefly Thames water after prolonged storage in reservoirs at Staines and Kempton Park).

(4) New River (Hornsey) filtration works.

(5) New River (Stoke Newington) filtration works.

(6) New River (Clerkenwell) filtration works (*i.e.*, mixed Lea (New River) and well-water, slight storage in Hornsey and Stoke Newington storage reservoirs).

(7) Southwark and Vauxhall (Hampton and Sunnyside) filtration works (*i.e.*, Thames water, mostly after storage in reservoirs at Walton and Hampton; also gravel water).

(8) Lambeth (Surbiton) filtration works (*i.e.*, Thames water after storage in reservoirs at Molesey; also gravel water).

(9) Grand Junction (Hampton) filtration waterworks (*i.e.*, Thames water after storage in reservoirs at Staines and Hampton; also gravel water).

(10) Grand Junction (Kew) filtration waterworks (*i.e.*, Thames water after storage in reservoirs at Staines and Hampton).

(11) West Middlesex (Barnes) filtration works (*i.e.*, Thames water after storage in reservoirs at Staines and Barnes).

(12) Chelsea (Surbiton) filtration works (*i.e.*, Thames water after storage in reservoirs at Molesey; also gravel water).

(13) Lea Valley wells (some of these are pumped into the Lea and New River, and some are used directly for supply purposes).

(14) Kent wells (all used directly for supply purposes).

(15) Additional wells (Streatham, Honor Oak, Selhurst, &c.).

(1), (2), and sometimes (3). Used for the supply of the Eastern district.

(4), (5), and (6). Used for the supply of

the New River district, and (3) really belongs to this district.

(7) and (8). Used for the supply of the Southern district.

(9), (10), (11), and (12). Belong to the Western district.

(13). Supplies both the Eastern and New River districts.

(14). Supply to the Kent district.

(15). Augments the supply to the Southern district.

4. RESULTS.—The results as regards the bacteriological quality of the water during the twelve months ended March 31st, 1908 (unless otherwise stated), will be considered under the following headings:—(1) Raw waters; (2) stored waters; (3) filtered waters and unfiltered well-waters.

(1) RAW WATERS.—*Average total number of microbes per c.c.* (*gelatine* at 20—22° C., colonies counted on third day). Thames, 3,170; Lea, 6,707; New River, 1,639.

Average number of microbes per c.c. (*agar* at 37° C., colonies counted on second day). Period of twelve months ended July 31st, 1908. Thames, 280; Lea, 382; New River, 88.

Average number of microbes per c.c. (*lactose bile-salt agar* at 37° C., colonies counted on second day). Period of twelve months ended July 31st, 1908. Thames, 41; Lea, 34; New River, 8.

B. coli test:—

PER CENT. OF SAMPLES CONTAINING:—

	1 or more B. coli. per c.c.	10 or more B. coli per c.c.	100 or more B. coli per c.c.	1,000 or more B. coli per c.c.	10,000 or more B. coli per c.c.
	%	%	%	%	%
River Thames	**83·2**	46·8	8·8	0·4	—
River Lea	**90·8**	46·8	10·4	2·4	0·4
New River	**49·6**	14·4	1·6	—	—

It will be seen that the raw waters contain a large number of bacteria, many of which grow at blood heat, and not a few in a bile-salt medium. Further, nearly one-half of the Thames, Lea, and New River samples contain at least 10, 10 and 1, *B. coli* per c.c. respectively.

(2) STORED WATERS.—As examples of stored water the Chelsea, Lambeth, and Staines (Thames water) and Lea (Lea water) stored water results may be given. The nominal number of days' storage being about fifteen, fourteen, ninety-five, and fifty-eight respectively.

Average total number of microbes per c.c. (*gelatine* at 20—22° C., colonies counted on third day). Chelsea stored water, 208; Lambeth stored water (ten months' average), 362; Staines stored water, 175; Lea stored water, 67.

Average number of microbes per c.c. (*agar* at 37° C., colonies counted on second day). Twelve months ended July 31st, 1908. Chelsea stored water, 44; Lambeth stored water (ten months' average), 52; Staines stored water, 34; Lea stored water, 11.

Average number of microbes per c.c. (*lactose bile-salt agar* at 37° C., colonies counted on second day). Twelve months ended July 31st, 1908. Chelsea stored water, 5; Lambeth stored water (ten months' average), 8; Staines stored water, 2; Lea stored water, 0·6.

B. coli test:—

PER CENT. OF NEGATIVE AND POSITIVE RESULTS.

Stored Waters.	Negative.	Positive.				
	100 c.c. %	100 c.c. %	10 c.c. %	1 c.c. %	0·1 c.c. %	0·01 c.c. %
Cols. 1	2	3	4	5	6	7
Chelsea.	**42·7**	24·7	19·1	10·1 (13·4)*	2·2	1·1
Lambeth.	**16·2**	32·5	27·5	16·2 (23·7)*	7·5	
Staines.	**33·7**	33·7	22·9	9·6 (9·6)*		
Lea.	**67·4**	26·9	4·5	1·1 (1·1)*		

* The figures in brackets are the aggregates of columns 5, 6, and 7.

The enormous bacteriological improvement in the raw water as the result of *storage* is

well shown by the foregoing figures. For example, 83·2% of the *raw* Thames samples contained *B. coli* in 1 c.c. of water. The corresponding figures for the Chelsea, Lambeth, and Staines *stored* water were 13·4, 23·7, and 9·6 respectively. In the case of the Lea the figures are still more remarkable, as 90·8% of the *raw* Lea samples contained *B. coli* in 1 c.c., whereas the corresponding figure for the Lea *stored* water is only 1·1%. As regards the latter water over two-thirds of the samples actually contained no *B. coli*, even in 100 c.c.

Streptococcus test.—The *raw* waters are also examined for *streptococci*, but these microbes are nearly always absent from 1 c.c. of the samples.

(3) Filtered waters (and unfiltered well-waters).—*Average total number of microbes per c.c.* (*gelatine* at 20—22° C., colonies counted on third day). It sometimes happens that samples of the filtered water collected from the separate filter wells at the works contain an enormous number of bacteria. The great majority of these microbes, however, are believed to be harmless, and not to be associated with imperfect filtration. To include these figures in the averages would create an erroneous impression, and so all samples containing 100 or more microbes per c.c. have been excluded from the averages given underneath :—

	Average Number of Microbes per c.c. (*exclusive* of those Samples containing 100 or more).
1. East London (Lea)	13·6
2. Sunbury (Hanworth). Results for 1907—8 not available.	
3. Kempton Park	25·3
4, 5 & 6. New River (Hornsey, Stoke Newington, Clerkenwell)	5·7
7. Southwark and Vauxhall .. .	12·7
8. Lambeth	6·7
9 & 10. Grand Junction (Hampton, Kew)	11·2
11. West Middlesex	9·2
12. Chelsea	6·3
13. Lea Valley Wells (excepting Rye Common and Amwell Hill), March, 1906, to March 31st, 1908	8·4
14. Kent Wells	5·6

The following statement indicates that the *exclusive* figures for the filtered waters were small, and the percentage reduction effected by the processes of subsidence and filtration remarkably good :—

	Thames.	Lea.	New River.
Raw waters (microbes per c.c.)	3,170	6,707	1,639
Filtered waters (microbes per c.c.)	11·1	13·6	5·7
Percentage reduction	99·6	99·7	99·6

B. coli test.—The percentage number of samples containing *no B. coli*, even in 100 c.c. of water, was as follows :—

	Percentage Number of Samples containing *no B. coli* even in 100 c.c. of water.
1. East London (Lea)	85·9
2. Sunbury (Hanworth). Results for 1907—8 not available.	
3. Kempton Park	90·1
4, 5 & 6. New River (Hornsey, Stoke Newington, Clerkenwell)	83·8
7. Southwark and Vauxhall	67·2
8. Lambeth	79·7
9 & 10. Grand Junction (Hampton, Kew)	79·0
11. West Middlesex	82·0
12. Chelsea	87·1
13. Lea Valley Wells (excepting Rye Common and Amwell Hill), March, 1906, to March 31st, 1908	92·0
14. Kent Wells	90·2

The remarkable improvement in the *raw* waters effected by the processes of storage and filtration may be judged by the statement that whereas the *majority* of the raw water samples contain *B. coli* in 1 c.c., only a *minority* of the filtered water samples contain this microbe in one hundred times as much water.

Type of B. coli.—As regards the *type of B. coli* in the raw and filtered waters, the following table shows that the filtered waters contain proportionately (as well as actually) fewer typical *B. coli* than the *raw* water.

TYPE OF *B. COLI.*

Type of *B. coli.*	*Raw* Waters. Out of 2,710 specimens of *B. coli* isolated from 750 samples of *raw* water the proportion between the typical and non-typical races of *B. coli* expressed as percentages was as follows :—	*Filtered* Waters. Out of 3,830 specimens of *B. coli* isolated from 7,797 samples of filtered water (including Kent and Lea Valley unfiltered well-water), the proportion between the typical and non-typical races of *B. coli*, expressed as percentages, was as follows :—
Typical *B. coli :* (+ lactose ; + indol)	81·6	54·4
Non-typical *B. coli :*		
(+ lactose ; − indol)	9·4 } 18·3	21·1 } 45·5
(− lactose ; + glucose)	8·9	24·4

5. RESEARCH WORK.—A great deal of research work is carried out at the Water Board's Laboratories. As yet (1908), however, only two special reports have been published on (1) "*The vitality of the typhoid bacillus in artificially infected samples of raw Thames, Lea and New River water, with special reference to the question of storage*," and (2) on "*The negative results of the examination of samples of raw Thames, Lea and New River water for the presence of the typhoid bacillus.*" As regards the former, the reduction in the number of the artificially added typhoid bacilli was over 99% within a period of one week, in all the eighteen laboratory experiments. A few of the typhoid bacilli, however, remained alive for from four to eight weeks. As regards the latter, 294 experiments were made with 156 samples of *raw* river water. The total amount of water dealt with was 29,400 c.c., containing in the aggregate, nearly 136 million bacteria. 7,329 microbes were specially studied, but none of them proved to be the typhoid bacillus. These 7,329 microbes formed but a small fraction of the millions of the other bacteria which were excluded owing to the temperature of incubation, the composition of the media employed, and the fact of their appearing one the plate cultures as coloured colonies. Undue importance, however, must not be attached to negative results.

6. REPORTS.—Reports as to the *quality* of the London waters are made each month, and are incorporated in the "Monthly Reports" of the Government Water Examiner, appointed under the Metropolis Water Act, 1871. Yearly and special reports are also issued from time to time by the Water Board. The former may be obtained from the publishers for the time being of Government Publications, and the latter from the Central Office of the Water Board, at Savoy Court, W.C.

7. SUMMARY AND CONCLUSIONS.—The Water Board supplies a population of nearly 7 million persons. The supply is derived from the River Thames (rather more than one-half); River Lea (nearly one quarter); and wells and springs (about one quarter).

Speaking generally:—

(1) The *raw* waters on an average contain between 1,000 and 10,000 microbes per c.c.; the filtered and well-waters between 10 and 100.

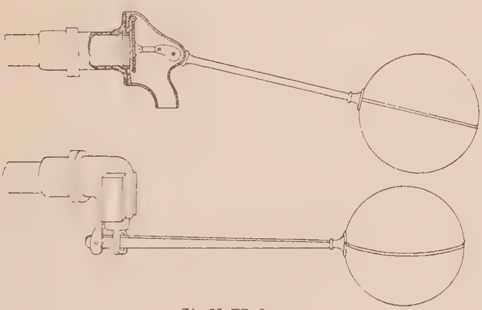
(2) The *majority* of samples of *raw* water contain *B. coli* in 1 c.c.; the *minority* of samples of the water actually sent into supply, contain *B. coli* in 100 c.c. These results are based on the results of the examination of between eight and nine thousand bacteriological samples yearly. The practice of the Water Board now is to store all river water, as far as this is practicable, antecedent to filtration. There are good grounds for believing that *adequate* storage can render an initially impure river water, relatively (if not absolutely) safe for domestic use. It is essential, however, to render a stored water bright, clear, and palatable, by subsequent filtration.

A. C. H.

"**Balancing Reservoirs**."—Small reservoirs or tanks introduced in a pipe-line conveying water with the object of reducing the pressure of the water on the lowest part of the pipes by breaking up the fall of the aqueduct, or pipe-line into independent sections. (*See* "WATER SUPPLY.")

Ball Valves.—Made use of to automatically regulate the supply of water to cisterns and tanks, and for maintaining the water at any given level. Made in various patterns, some to open vertically, some horizontally. They all consist of a valve acted upon by a lever having a hollow copper ball at the extreme end, which floats on the water in the cistern.

When the water sinks, by being drawn off, the ball drops and opens the valve, or allows it to be opened by the pressure of the water in the main. When the cistern is full the ball is raised and the lever made to close the valve. The length of the lever, and the size



Ball Valves.

of the copper ball or float are regulated by the diameter of the supply pipe and the pressure of water in the main. The longer the lever and the larger the ball, the greater the pressure brought to bear on the valve. Ball valves should be made to resist from four to six times the pressure ordinarily pressing against them, because on quickly closing a cock, the ordinary pressure is considerably increased by the shock or water hammer. They should be tested to act to their full pressure when the ball is half immersed. The valves should be made of hard brass or gun metal, and may be faced or provided with leather or vulcanised india-rubber washers.

Barometer.—People are not always conscious of the presence of the air around them, as it is invisible; but they feel its effects when it is in motion, as in wind. Air, however, has weight, which is equal to 14·7 lbs. to the square inch. It is this weight which raises the water in the common pump to the height of about 34 ft., this being practically the balance of the weight of the atmosphere. As mercury is about thirteen times heavier than water, a column of about 30 in. of mercury is held up in a tube which has been freed from air, by the pressure of the atmosphere, and such a column of mercury is used as a barometer, for showing the changes in the weight of the atmosphere. The best form of barometer is that of the Fortin pattern. This has an adjustable glass cistern in order that the surface of the mercury therein can be brought into contact with the ivory point which forms the extremity of the scale. In the Kew pattern of barometer (which is largely used by meteorological observers), the cistern is rigid and closed, but the error arising from the change of level in the cistern (technically termed the "error of capacity") is overcome by contracting the divisions on the scale. Every barometer has a thermometer fixed to the brass tube, in order to show the temperature of the mercury in, and the scale of, the barometer.

The mode of taking an observation is this:—First note the reading of the attached thermometer; then (if the barometer is a Fortin) adjust the mercury in the cistern by turning the screw at the bottom, so that the ivory point is *just* brought into contact with the surface of the mercury, but does not depress it; the ivory point and its reflected image in the mercury should appear to just touch each other and form a double cone. Next adjust the vernier so that its two lower edges shall form a tangent to the *convex* surface of the mercury. Then read off on the scale by means of the vernier to the thousandth of an inch. Having obtained the actual reading of the barometer, it now requires to be corrected for (1), index error, and (2) temperature. The correction for (1) will be found on the Kew certificate if the barometer has been verified at the Kew Observatory. The correction for (2), viz., reducing the reading to the standard temperature of 32° F., can be found in Table I. of "Hints to Meteorological Observers."

The barometer should be fixed at such a height that the observer can read the vernier comfortably when standing upright; it must hang vertically and be in a good light. Barometers should always be very carefully handled, so as to avoid breakage, or admission of air into the tube. It is best to carry the instrument with the cistern end upwards. In the case of a Fortin barometer, the mercury should be screwed up so as to fill the tube and cistern before the instrument is taken down.

Another form of barometer is the aneroid. This is an instrument consisting essentially of an elastic metal box, exhausted of air, which indicates on a dial the changes due to variations of external pressure on the box, and therefore, acting as a barometer. Aneroids are very handy and useful instruments; they, however, should not be absolutely relied upon for long periods, but should be checked from time to time against a mercurial barometer.

A self-recording aneroid or barograph is an interesting instrument, as it yields a continuous record of the variations of atmospheric pressure. As the pressure of the atmosphere diminishes according to altitude, the barometer is often used for the measurement of heights. In comparing barometric observations made at different places, account must be taken of their respective heights above sea-level; for the higher the station, the lower will be the reading of the barometer. So for the preparation of isobaric maps it is necessary to reduce all the readings to sea-level. Tables for this purpose will be found in the "Hints" referred to above. W. M.

Baths for domestic purposes are made in a variety of shapes and sizes to suit special requirements. The normal dimensions of "full-size" baths are:—

	ft.	in.
Length	5	6
Breadth at head	2	1
Breadth at foot	1	8
Depth	1	10

These dimensions are all internal. It is usual for baths to taper from head to foot and from top to bottom to economise water. When the users are above average size or stout, "parallel side" baths should be made use of as allowing more room. Baths are made of various materials, such as zinc, copper, cast-iron, fire-clay, marble, and steel. Zinc baths are not durable. They were formerly much used for cheapness, but cast-iron baths are now made equally inexpensive, and prove much more satisfactory, and have therefore almost entirely superseded them. Copper baths are also out of date, mainly by reason that they have to be fixed in cradles and enclosed in wood to prevent them from losing their shape. They have the advantage that they do not absorb much heat from the water. "Porcelain" or fire-clay baths are not now so frequently used as formerly. They are heavy, cold to the touch, comparatively expensive, and very liable to fracture. Much the same remarks apply to marble baths, which may be cut from the solid block or made up of slabs. The more generally useful and satisfactory baths are made of cast-iron, porcelain, or vitreous enamelled. The former are the better, but the latter are slightly cheaper. Porcelain enamelled steel baths stamped from the sheet are of recent introduction. They promise to combine the advantages of the iron baths with cheapness and light weight, but have not at present had a sufficiently long trial to warrant a judgment as to their durability. All baths should be fixed without enclosures.

Baths, Open-Air.—**Site—Accommodation—The Swimming Tank—Entrance Lodge—Dressing Boxes.**

Site.—This should be preferably in a public park or in some open spot. The land should be fairly level, and lend itself to enclosure without being unsightly. If the site is surrounded by a belt of trees so much the better.

Accommodation.—After settling upon the site, the next point will be the accommodation required. This is generally as follows:—Swimming bath, entrance lodge, conveniences, dressing boxes or sheds, slipper and shower

baths (sometimes). As the "open-air treatment" is the main feature of this type of bath, slipper baths are very rarely required.

THE SWIMMING TANK.—This may be either sunk in the ground or built on the ground. The more convenient way seems to be the former. The size must be decided upon according to the number of bathers expected. The depth should be from about 5 ft. at the shallow end to 10 ft. at the deep end, the water-line being 1 ft. below the top of the coping round the bath edge. The walls will be constructed of concrete, either reinforced or ordinary concrete construction. A rough method of calculating the thickness of the wall is as follows:—

Thickness at top of wall = height × ·30
,, ,, middle of wall = ,, × ·50
,, ,, bottom ,, ,, = ,, × ·70

This is only approximate, but is on the safe side. To get the accurate thickness of wall, diagrams of the thrust must be drawn.

The walls should be constructed in two thicknesses, the outer portion having wall ties embedded every yard—one to every yard super of wall face. Over this face is put the bitumen sheeting for making the tank watertight; and the inner wall—about 6 in. in thickness—is then constructed, being held to the outer portion by the wall ties.

The floor is constructed in a similar manner, *i.e.*, in two thicknesses, having bitumen between the layers, which should not be less than 4½ in. in thickness. The top layer of the concrete floor should be constructed in alternate squares, about 6 ft. sides to allow of uniform shrinkage.

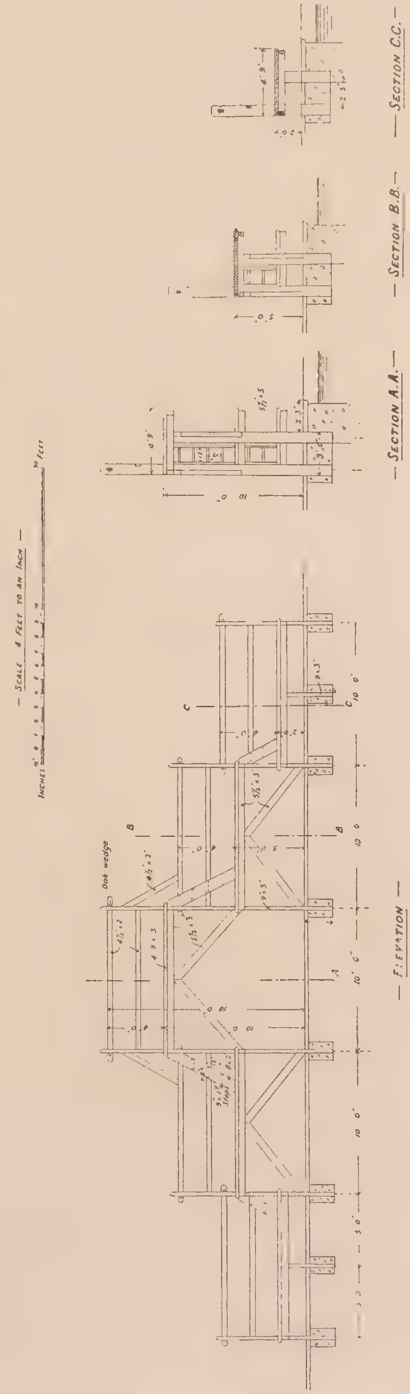
A handrail should be fixed round the inside of the bath, 1 ft. from the top of the coping.

The coping should not hang over the edge of the bath more than 2 in.

Gangways round the bath should be wide and paved with either stone or granolithic, falling *away from* the edge of the bath to a channel.

Diving-stages, platforms, and water-shutes should be provided. Oiled teak will be found the most serviceable for the diving stages. The steps of the stage should be covered with indiarubber to give a firm foothold.

Steps should be provided leading into the bath at each corner, either of stone or teak.



Details of Diving Boards at Tooting Common Swimming Bath. Design by P. Dodd, Borough Engineer, Wandsworth.

If of teak, lead should be fastened to the bottom step to keep same from floating.

Entrance Lodge.—This should contain room for the attendant and pay office. Conveniences may be placed at each side of the entrance, having entrances both from the inside of the bath enclosure and from the outside, so that when the bath is not in use the conveniences may be used by the outside public. Accommodation should be provided for both sexes.

Dressing Boxes or Sheds.—These should be placed either round each side or along one or more sides. They may be either separate dressing boxes or one long shed with seating accommodation, and hooks for clothes.

It will be found possible to use the earth excavated from the bath tank as a screen round the bath by forming an embankment.

The dressing boxes or sheds may then be either on one or any of the sides.

If any open shed is provided, provision should be made for temporary division into compartments when it is women's day. Curtains will be found sufficient for this.

(For Acts of Parliament, *see* below.) R.H.B.

Baths, Public Swimming and Slipper. **—Acts of Parliament—General Considerations—Swimming Hall—Bath—Corridors—Gallery—Diving Platform—Attendant's Cabins—Water Shute — Entrances — Club Room — Pay Box—Ventilation and Warming — Slipper Baths — Superintendent's Apartments — Establishment Laundry—Boiler House—Temporary Floor—Continuous Filtration.**

Acts of Parliament.—The Acts of Parliament governing the provision of Public Baths commenced with the Bath and Wash-houses Act, 1846, which is an adoptive Act. This Act entitles public Authorities to erect suitable buildings for public baths and wash-houses, and also make open bathing places, and convert any building for the same use. After seven years' use the public authority may sell the buildings and land, if they should find that their working is too expensive. An important section is that which provides that a copy of the Bye-Laws made in respect of this Act shall be hung in every bath-room. Section 36 provides that the number of baths for the working classes shall not be less than twice the number of the baths of any higher class if but one, or of all the baths of any higher class if more than one, in the same building. Schedule B relates to the scale of charges, but was subsequently repealed and amended. The Act was amended in 1847, extending its power to further authorities and also regulating the number of first- and second-class washing troughs on the same basis as the slipper baths referred to in section 36 of the first Act. The amended Act of 1847 contains a revised list of charges for the use of the baths. The Act was again amended in 1878 to allow the bathing places mentioned as being "open" in the 1846 Act to be roofed over. The Act also limits the period during which a swimming bath may be closed to an extent of five months in any one year beginning with November and terminating at March. The local authority may during that time use it as a gymnasium or place of recreation, or for parochial meetings, but not for music or dancing. The Act also contains a list of charges relating to covered swimming baths. In 1882 the Act was once more amended in order to allow of baths, &c., being erected outside the parish but within easy distance of same. The amendment of 1896 repealed section 5 of the Act of 1878 which debarred the use of the bath during the winter season for the purposes of music and dancing, but only so far as London was concerned, and then only after an application made to the London County Council. However, in the year 1899 section 5 in the Act of 1878, which was still in force everywhere except in London, and which prevented the use of the building for music and dancing, was repealed, and the buildings could thenceforth be used for that purpose, subject to permission being obtained from the County Council of their several districts.

General Consideration of the Subject.—When considering the question of public

baths, there are several views which might be entertained, namely, whether it is more desirable to group the swimming baths, slipper baths, and wash-houses in one centre, than to build say, a swimming bath in one spot, generally accessible to the whole town, and to erect one or more buildings containing slipper baths in other parts, preferably congested areas. The status of the town would likewise determine whether there should be a first- and second-class bath and also a separate bath for women, or whether it would be more economical to set apart a certain day when the first- or second-class baths could be reserved for women. There is often an objection on the part of women to the latter arrangement, as it is frequently inconvenient for persons to so regulate their appointments that a swim if desired must be taken on a certain day and at a particular hour, while the men on the other hand object to being closed out on perhaps the only day of the week when their business will allow them to be free. Again the size and character of the baths will be determined by the conditions of the neighbourhood. In some places there will be a greater demand for a first-class swimming bath. In another there may be a preponderance of school children which will require more attention being paid to baths for their accommodation. A wash-house or public laundry will be much in demand in a poor neighbourhood, and as such, should receive a considerable amount of attention, but its entrance and general position should be kept as far away as possible from the other portions of the building, and provision be made for the sundry perambulators, mail carts, &c., used by the customers for the transit of their laundry work. The shape and position of the site are important matters, both with regard to the initial cost, subsequent up-keep, and convenience of administration. A long narrow site will necessitate long corridors, costly in their design, awkward for the public and difficult in supervision.

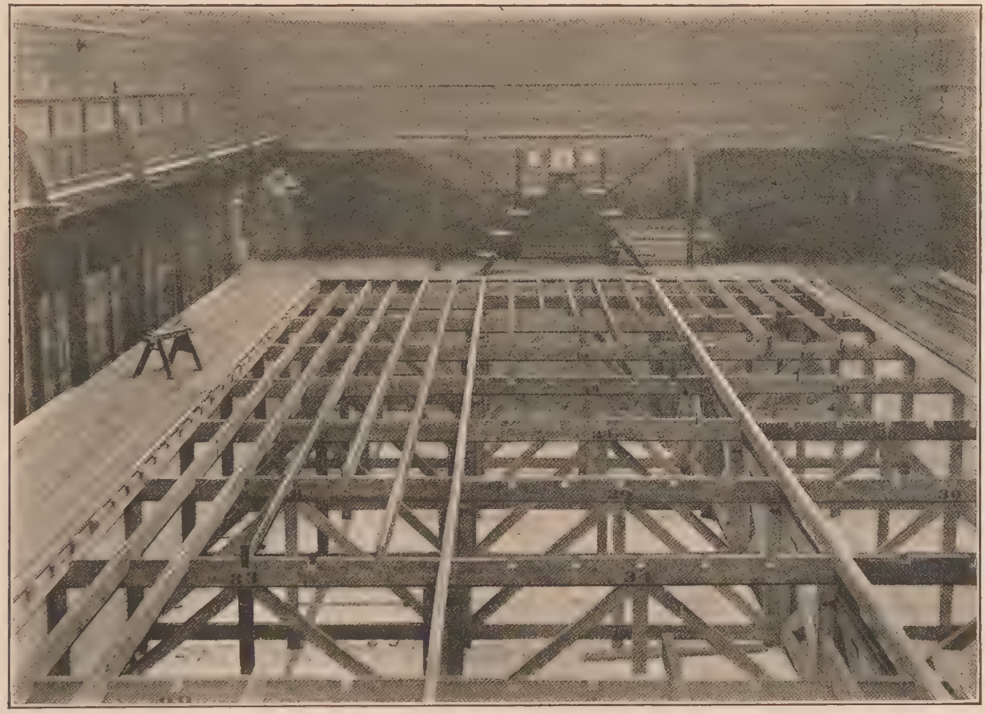


Fig. 1.—Temporary Floor for Public Swimming Bath. Designed by R. J. Angel, A.R.I.B.A.

The Swimming Hall.—The internal faces of the walls should be of red pressed bricks as they are not liable to condensation and a glazed brick dado shoulder high should be provided. Some slight attempt at architectural treatment might be indulged in by forming pilasters under the roof-trusses with string courses and ornamental bands, and segmental arches or oversailing courses at the eaves. It is not advisable to construct any windows which will admit direct sunlight, particularly on to the water as it not only annoys the bathers but promotes vegetable growth within the bath. The roof-truss should be of iron, and its design is a matter for the architect to decide. Some roofs are sloped to an ordinary pitch, with either a flat or curved tie rod, and boarded on the underside with diagonal boarding and the usual lantern lights along the apex; while other roofs of successful design have been formed of segmental section with curved lattice principals. It is usual to form the sides of the lantern with fixed wooden louvre boards for natural ventilation, but if the bath is to be ventilated in such a manner as to free the entrance doors as much as possible from draughts and an in-rush of cold air, the plenum system seems to be the one best adapted. In that case there should, of course, be no open louvres in the roof. All glass in the roof should be wired with netting within the thickness of the glass. The artificial lights, whether gas or electric, are best kept away from the centre of the pond, and placed so as to be accessible from the gangway. The swimming bath is generally the one item which determines the whole plan, and is the making or marring of the scheme. The swimming bath should be so planned that it may be most convenient not only for its obvious intention, namely, a bath to swim in, but also a bath in which competitions may take place and be viewed by the public, and in addition to this be used during the winter season as a public hall. In order to be used for the two latter purposes, convenient entrances, exits and emergency exits, both from the gallery and floor level, should be provided, together with facilities for receipt of entrance fees.

The Bath.—The best manner to form the excavation is to dig out for the exact size of the boundary walls of the bathing hall, carrying the footings of the walls down to the level of the bottom of the bath, utilising the intervening space between the wall and the bath for laying the pipes and allowing sufficient room for workmen to execute repairs. The length of the bath along the waterline, should, for racing purposes, be a fraction of a mile, thus 105 ft. 7 in. equals one fiftieth of a mile and this is for all purposes a convenient length, although some are made 132 ft. or one fortieth of a mile. A short or an odd length will be sure to produce dissatisfaction among expert swimmers. The width should not be great, no advantage being obtained by making it anything over 30 or 36 ft. wide (numbers dividable into yards). It should be remembered that an increase of width means a larger proportion of expenditure in construction than would be the case with an increase in length, as heavier scantling is required for the roof, and more material both in roof covering and bath construction, both of which are expensive items. The depth of the water should vary from 3 ft. 6 in. to 6 ft. 6 in., and the bottom slope of the bath should run in an even gradient from the shallow end to about 10 ft. from the deep end, the latter 10 ft. having just enough slope to drain itself. Ladies' baths, however, should be about 50 ft. long by 25 ft. wide, and with 3 ft. 6 in. to 5 ft. 6 in. depth of water. The floor of the bath should be formed of concrete of an even thickness of not less than 2 ft. It is advisable to form the excavation to the same slope as the bath floor, not as is sometimes done by stepping the excavation in level sections and forming the top surface of the concrete on the slope. This method will exhibit a weak spot where one step joins another and tends to produce a crack due to the unequal contraction and expansion of the material. It is, however, advisable to roughen the surface of the excavation to avoid any tendency of the concrete to

"creep." The concrete bottom should be carried under the sides of the bath and project on the outside for at least a foot. The sides of the bath should for preference be of concrete ramped or stepped in varying thicknesses from 4 ft. at the base to 18 in. at the top. Buttresses at intervals should not be built, but the wall should be constructed of continuous thickness, each diminution of thickness being perfectly horizontal. The inside face of the concrete should be left rough to provide for a layer of asphalte being put as a waterproof covering over all. This asphalte should be about an inch thick laid in two thicknesses and of such a consistency that it will not run when the temperature of the water is raised. The interior of the bath is lined with 4½ in. white glazed bricks on the sides, varied sometimes with a coloured (green) band along the top courses. It is not necessary to tie this 4½ in. lining into the main body of the work. The bottom of the bath may be either "brick flat," brick-on-edge, or thick tiles, the whole very carefully jointed with Portland cement compo. It is advisable to fill the bath with water after the asphalte

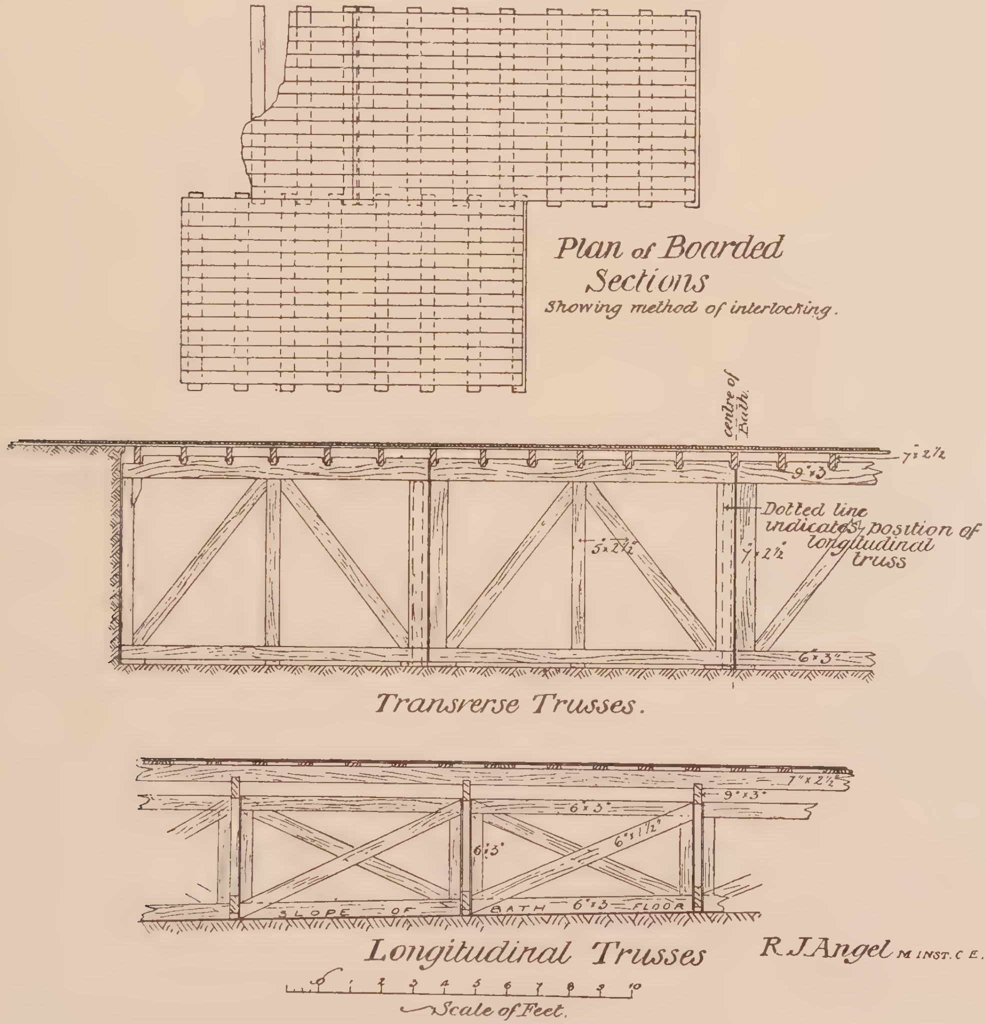


FIG. 2.—Temporary Floor for Public Swimming Bath. Designed by R. J. Angel, A.R.I.B.A.

has been finished and before the brick lining has been commenced so as to test for water leakage. It is, of course, assumed that the earth forming the foundation of the bath is firm and secure, any defective portion being dug out and the hole filled with concrete. There is no advantage to be obtained in using reinforced concrete in either walls or bed, as it does not need so much as a "collapse" to destroy the utility of the work, a simple crack or fissure being quite sufficient to ruin the watertightness of the bath, and this is just as likely to occur with reinforced work as without it. Especial care must be taken in building-in all connections to pipes. It is as well to have a double flange to such connections, one placed on the inside of the bath and the other outside, and packing the concrete in between. All such connecting pieces should be built in as the concrete is laid. Overflows and scum troughs should be formed on the sides and more particularly at the deep end; and also places where bathers can spit, although in some of the newer baths this latter has been omitted, but whether provided or omitted the tendency to spit exists so that it is better to provide for it than to allow bathers to expectorate in the water or on to the gangway. A handrail of galvanized iron tubing about 2½ in. diameter should be placed about 2 in. clear of the water. The top of the gangway should be about 15 in. above the water line. It is assumed that there will be a passage formed around the walls of the tank itself for pipes, &c., so that the floor or gangway around the tank will form the ceiling or covering to it. This gangway should be of steel girders in concrete and covered with some non-absorbent and non-slippery paving material. York flags and slate have been used, but both these are undesirable; certain qualities of red tiles are better, and one bath in London has a flooring of rubber tiles, but this has a tendency to allow water to percolate between the joints. Great importance must be paid to the non-slipperyness of the paving material. The curb around the bath may be a 4 in. finely tooled or rubbed York stone with a round nosing. This gangway should be from 4 ft. to 4 ft. 6 in. wide, and if chairs are to be placed along the gangway during entertainments it should be 5 ft. wide. Considerable space should be allowed at either end as it is there people mostly congregate—there should certainly be a not less space than 12 ft. at the deep end as races generally start from here and the opposite end may be 6 or 8 ft. wide. The gangways should have a slope from the water's edge towards the dressing boxes, and a shallow channel be formed next to the boxes, with trapped galvanized gullies at intervals. The dressing boxes should only be ranged along the long sides of the bath and should be raised above the gangway by a 2½ in. to 3 in. step. The floor of the dressing boxes should be of maple as this is the best wood to use where the floor is constantly wet. The size of the boxes ought not to be less than 3 ft. 6 in. by 3 ft. 6 in. for the first-class baths and 3 ft. by 2 ft. 9 in. for the second-class. The framing should be of pitch pine or teak, framed with as few internal angles as possible, of light scantling compatible with strength, and filled in with panels in preference to either beaded or V-jointed boarding. The door should be about 4 ft. 6 in. high and in the case of the women's bath there should be a rail and curtain provided to fill up the space to the top of the box. The width of the doors need not be more than 27 in. and the remaining portion of the front may be carried up to the top of the box. In some of the more recent baths the door is also carried up for the full height, but the upper panels are in the form of a grill. In the latter case the latch which is provided should be opened on the inside with a knob and on the outside by an attendant's key. The door, and sometimes the framed divisions, are kept off the ground about 3 or 4 in., but the latter in some localities is open to objection as it leads to the temptation for articles, such as boots, clothing, &c., which may be on the floor being stolen by persons in the adjoining box. In the public baths at Camberwell and Hoxton the framing is made collapsible and folds back

against the wall, the seat also being hinged, allowing of a considerable area being thrown into the hall for public meetings. A fixed seat (capable of being unscrewed), a slatted footboard, two hooks, and a mirror complete the furnishing of the dressing box. No steel or ironwork should be used for the fittings, even the butt hinges on the doors should be of brass, so as to dispense with liability to rust. The feet of the uprights should be let into galvanized sockets set in the concrete floor to protect the wood from damp. There should be two w.c.'s and urinals for each class of bath, and it is advisable that they should be in a compartment leading off the main hall. A foot bath about 18 in. deep should also be provided somewhere near the entrance so as to be under the control of the attendant and supplied with warm water, its size being about 4 ft. by 3 ft. and have an outlet for the rapid discharge of water. A wooden seat should be ranged around three sides where several bathers may sit together and cleanse their feet before entering the bath. This is especially useful where schools attend the baths. A shower bath, if provided, should be separated from the foot bath, it can then be used independently and need only be sufficiently large for one person to stand in. Most public baths are now provided in either the first- or second-class divisions with a gallery for the public to view entertainments. This is mostly done in the first-class bath. The gallery should comply with the local regulations with respect to safety of places of public entertainment. The regulations in force in London are mostly followed by the provincial towns and are set forth in an amended form dated 13th November, 1906, and entitled "Regulations made by the (London County) Council with respect to the requirements for the protection from fire of theatres, houses, rooms, and other places of Public resort within the Administrative County of London." The chief points affecting public baths when used for entertainments are that each gallery accommodating not more than 300 persons must have two exits each 4 ft. wide. There shall be no recesses along the walls within 5 ft. from the floor; all staircases must be of stone or other incombustible material and 4 ft. wide, with steps having 11 in. treads and 6 in. risers with no winders, and not less than three steps in a flight or more than fifteen without an intervening landing. All doors shall open away from persons leaving the hall and have panic bolts fitted and be hung in two leaves. Swing doors for the interior are preferable. All doors leading out to be properly marked with the word Exit.

Corridors and Passages.—The corridors and passages throughout the building are best lined with glazed bricks, and the floors covered with Terazzo or Mosaic tiles, as they are easily cleaned.

Gallery.—The design of the gallery should be such that the water may be seen for its full width by all persons when seated. This will probably mean that the steps carrying the seats must be fairly steep. There should be nothing movable, and all timbers, especially the gallery front, should be extra strong to provide against danger arising from the public pressing forward. There should be no means of communication between the body of the hall and the gallery, which should have its own separate entrance and emergency exits. The gallery could very well be carried around each of the four sides of the hall, supported over the boxes by thin columns designed to coincide with the divisions between the compartments, but at either end of the bath, where there are no boxes, the columns should be omitted and cantilevers used.

Diving Platform.—A diving stage is provided at the deep end of the bath in the form of three steps, the bottom step being about 2 ft., the next 4 ft., and the top 6 ft. above the gangway level. Sometimes there is only the one provided, at a height of about 2 ft. 6 in., and this as long as possible.

Attendant's Cabins.—A cabin for the attendant, stores for used towels (or a shute for same to the basement), should be provided, and also accommodation for brushes, buckets,

&c., &c. These compartments are usually near the entrance.

WATER-SHUTE.—A shute is also a useful adjunct to the bath, formed of teak 24 in. wide by 3 in. thick, with sides projecting 3 in. above the surface. The shute is hung on rods from the roof principals, a spray is fixed along the top end, and the shute is reached by a fixed ladder.

ENTRANCES.—The entrance to each of the bathing halls should be through a short vestibule having folding doors at each end so as to cut off all draughts, and screen the hall from observation. The entrance is generally at the deep end of the bath.

CLUB ROOM.—In baths of any distinction, there should be a room for the use of clubs and committees, designed so as to be accessible both from the bathing hall and also from the corridor outside. Also an artistes' room may be provided somewhere near the deep end of the bath.

PAY BOX.—The pay box is generally at the front of the building, and so placed as to divide the first from the second-class entrances, each entrance serving both the swimming and slipper baths in their respective class. It is advisable to provide a separate pay box for the women's slipper baths (and also for their swimming baths if one is provided). Their entrance should not be through the same door as the men except on days when the women use either the first- or second-class swims, in the absence of a special bath being provided. If properly designed, the men using the slipper baths and the women passing into the swimming bath on their special day will be effectually separated. It is as well to so place the first- and second-class swimming baths that they should be divided with the same division wall; this will economise the piping and simplify the construction, and as a door of communication could be provided it will be found very useful on gala nights, to swim off the first heats of a race in the otherwise vacant bath, while the entertainment is progressing in the other.

VENTILATION AND WARMING.—The ventilation of the large bathing hall is a matter which should receive keen attention. Unless great care is exercised draughts will ensue, or else an unpleasant steamy odour will exist, especially when large numbers of bathers are using the water. When schools are bathing this smell is very evident. To efficiently ventilate so large a hall when used either for bathing purposes or public meetings, it is quite useless to depend on natural ventilation. On the one hand, the air may be exhausted by an electric or water-power fan (the water being used either for flushing or in the bath), placed in the roof and dry warm air admitted by Tobin's tubes, placed 6 ft. above the floor, or the Plenum system could be adopted, whereby dry, warm air could be admitted at the eaves line of the roof, and expelled through apertures near the base of the wall, which are connected continuously to ducts passing through the subway. There are advantages and objections to both systems. In the first, the distribution of the fresh air may be unequal and unpleasantly severe in the neighbourhood of the inlet, and cause an inrush of cold air at the entrances each time the doors are opened, while in the second instance, vermin may get into the duct, especially at baths where large numbers of lower class school children bathe. Mr. Aldwinkle, F.R.I.B.A., has overcome the objection of the large amount of cold air which accumulates in the upper part of the roof of the hall, by discharging warmed air above the line of the eaves, on the Plenum system. Hot water pipes on the low pressure system are frequently laid along the sides of the hall, behind the dressing boxes—useful on occasion of public meetings, and also at certain times of the year when the hall is uncomfortably chill to bathers.

WAITING ROOM.—Adjoining the entrances there should be a waiting room for each sex and each class of bathers, awaiting their turn to use the slipper baths. The slipper baths should be accessible immediately out of this room, and long corridors avoided.

SLIPPER BATHS.—It is necessary when preparing the design to recollect that portion of

the Act which requires twice the number of second-class baths to be provided as there are in the first-class. The size of a slipper bath-room is about 6 ft. wide by 6 ft. 6 in. long. The baths are placed in pairs on either side of the dividing partition. It is best to design the arrangement, if it is possible, so that the room containing the slipper baths may be about 17 ft. wide, and have windows on each side. This will allow a row of bath-rooms to be erected along each outer wall, lit by direct daylight, and separated by a central corridor 4 ft. wide. The flooring may be of concrete, granolithic or mosaic. The partitions are generally 6 ft. 6 in. high and 1 in. thick. It is not advisable for the division to be fixed so as to leave a space at the floor line. Articles of clothing may drop and get kicked into the next compartment, or be stolen. The space causes a considerable draught, and there is not that idea of privacy which is desired. Moreover, in washing one bath, the adjoining one gets wet. Enamelled slate is the best material for both division and door. Marble looks much better but is more costly, and is very liable to fracture along the veins. If the doors, which should be about 27 in. wide, are made about a $\frac{1}{4}$ in. less in width than the opening, there will be no fear of their breaking, especially if a rubber buffer be also fixed. The top and bottom of the slate divisions, and also the door, should have a cast iron grooved capping to connect each width together, and the several widths of slate should be dowelled together with copper or gunmetal dowels. The room containing the slipper bath-rooms should be at least 12 ft. high if there is a flat ceiling, but an open roof is to be preferred, with a closed lantern light over, which will adequately light the central corridor. There should be an external window to each bath-room if possible. Where the exigencies of the site do not allow of all classes of slipper baths being on the ground floor, it is usual to place the first-class on the floor above. The baths are either porcelain or the newest type of enamelled iron, and should be of the pedestal pattern. Porcelain is often objected to on account of its coldness. A wooden top should be provided over the bath, of unpainted yellow pine, $1\frac{1}{2}$ in. thick; also a seat, and hooks for clothes, and a slatted footboard. Within the large room containing the several slipper baths, there should be w.c. and urinal accommodation and, situated near the waiting room, an apartment should be provided for the attendant. Each bath-room should be connected with this room by an electric bell. If the relative position of the room will permit, there could be provided with advantage, a shute for soiled towels from the bath-room to the establishment laundry. The room containing the slipper baths should be amply lit by artificial light. If by gas, one bracket could be fixed so as to serve two baths. They will probably be kept alight the whole evening, but if electricity be available, a light could be provided in each bath, each controlled by a separate switch. The locks for the bath-room doors should be of a simple kind, capable of being drawn back with a knob from inside, and opened with a key by the attendant. These slipper baths should be warmed with pipes or hot air as previously described.

Superintendent's Apartments. — There must be a suite of apartments for the bath superintendent, generally consisting of six or seven rooms and arranged in the front of the building on the upper floor.

Establishment Laundry.—There must also be an establishment laundry where the towels and bathing costumes are washed. This room is generally in the basement, and contains a mechanical washer, a boiling and rinsing tank, a hydro extractor and mangle, all driven by machinery. Also a set of drying horses, containing about twelve divisions according to the size and requirements of the premises. The heat might very well be circulated by a small motor fan. In all respects the horses should be constructed in the manner described under that head in the article on Public Wash-houses. The motive power for all the machinery might with every economy and convenience be electricity, if it is available, as it is most important to economise labour and

do away with constant attendance of the staff. The boiler-house should be so placed that there may be a good height for circulation of water to the various baths. It should also be so placed that a boiler can be taken in and out without causing much damage to the building. Convenience for taking in coal should be considered.

Store Room.—A store room for towels, bathing costumes, soap, &c., should be provided and fitted with clean wooden racks. The room should be heated and ventilated.

The Boiler-House.—It will probably be found that three boilers will be required, of Cornish or Lancashire type, with a length of say 30 ft. and a diameter of 6 ft. to 6 ft. 6 in. each. This will be a guide to the dimensions of the room required. The boilers will be required to supply steam for the swims, hot water for the slipper baths, and hot water and steam for the wash-houses. The water in the swimming bath is generally heated by injecting steam into the bath full of water, or, it may be, by circulating the water through a calorifier, which can be done with spent steam supplemented with a small quantity of live steam, which is certainly the cheapest and most satisfactory way of keeping the temperature even and properly distributing the warmed water. Ample storage for coal must be provided. Each of the boilers should be capable of doing the same work and be of similar construction. A large storage tank for cold water must be provided with enough head to quickly supply all water which may be required for the slipper baths, laundries, boilers, &c. The circulating pipes are laid to the swimming bath along the subway arranged around the tank, and all other pipes and wastes are laid in channels formed so as to be capable of easy inspection and covered with chequered plating. It is a great convenience to place a 2 in. pipe across the width of the swimming baths at the shallow end with perforations for spraying cold water along the surface of the water towards the deep end, and so driving out any scum which may collect. The fittings for supplying hot and cold water for the slipper baths should be of a simple character and capable of properly mixing the hot and cold water. Such fittings are, of course, controlled from outside the bath-room by the attendant.

The Temporary Floor.—If the bathing hall is to be used as a place for public meetings, the bath must be covered over with a substantial floor. It is important that the substructure should be strong and the boarded covering framed so as not to creak when persons walk across it. The floor which is illustrated was designed by the author with these objects in view. The trusses arranged across the bath were in three sections, the headpiece 9 in. by 3 in., the sill 6 in. by 3 in., uprights 7 in. by $2\frac{1}{2}$ in., struts 5 in. by $2\frac{1}{2}$ in. The top of the headpiece was notched to receive joists which were 7 in. by $2\frac{1}{2}$ in. and 18 in. apart. These joists were also partly notched to fit on to the trusses and were in as long lengths as could be obtained, but so that their ends "broke joint." The top surface of the joists was level with the gangways around the bath, so as to allow the wooden floor to cover the entire area. Between these cross trusses there were placed two rows of longitudinal trusses having 6 in. by 3 in. head, sill and uprights, and 6 in. by $1\frac{1}{2}$ in. cross bracing screwed on to each side. Each truss was secured to its neighbour by a hasp and staple—the staple, however, being in the form of a peg which secured itself when turned. It was desirable for dancing that the joints of the boards should be in the direction of the length of the bath. The flooring consisted of 6 in. by $1\frac{1}{2}$ in. tongued and grooved boards, screwed to 6 in. by $1\frac{1}{2}$ in. cross bearers. The floor was formed into sections 6 ft. by 4 ft. Three bearers were provided to each section, and as the end of each bearer projected 2 in. beyond the side of the boarding, each section became interlocking and self-securing, and its united weight kept it rigid. A specially formed section, tapered down, was provided near the doorway and the joint between the wood section and the tiled floor covered with a mat. A trap-door in one section gave access to the

bath where it might have been necessary for an entrance to be obtained to wedge up. It is important that a floor of this kind should have a special place in which it can be stored away, as each section should be laid flat and kept from twisting by the weight of the members above. Each part of the floor is numbered and laid in its place according to plan.

Continuous Filtration of the Water in the Swimming Bath.—It is impossible to work a public bath so that it will be self-supporting in the matter of current expenses. The capital charges are heavy and the cost of maintenance and repairs also very great, consequently everything should be done to lessen the latter as much as possible. But it is not with that object principally in view that a system of systematic filtration has been adopted; it is for the purpose of keeping the water at one degree of continuous purity that the installation has been in use. Take for instance the general run of one filling of the bath with water, which will probably remain fit for use for three days. It may be considered quite pure for say one or two hours; at the end of a day it will present the appearance of being different from drinking water, but at the end of three days it becomes necessary to discontinue its use, and yet some swimmers bathe in it up to the last moment. The plant in question never allows the water to get beyond the impurity of an ordinary bath water two or three hours old, and the water used with this system remains in use at the Rotherhithe Baths, where the author has installed the scheme, for three or four months at a time, including the summer season. The results have been tested both chemically and bacteriologically by eminent analysts and pronounced perfectly satisfactory, while the minor question of economy is equally gratifying to the Council.

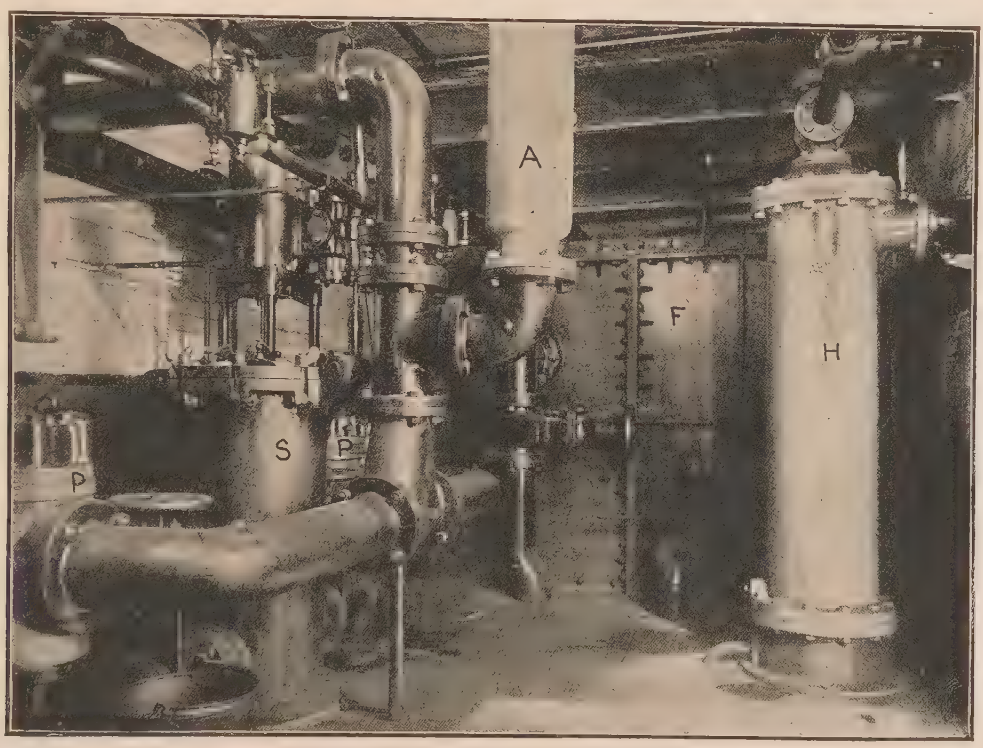


Fig. 3.—Continuous Filter.

The following advantages are claimed for

continuous filtration :—(1) The water is never allowed to get into an unclean state, such as may be the experience of the last bather in water ready to be thrown away under the old system. (2) The water is uniformly heated throughout at all times, and those cold areas which exist during the first hour or two in water heated after filling are avoided. (3) A total absence, even in a crowded bath, of that close "body" smell so well known in the atmosphere of most public swimming baths which are much used. (4) A continuous current of water is maintained through the bath. (5) Economy of water. (6) Saving of time of the employees attending in the early hours of the morning to heat up a fresh bath. In the purification of the water there are three different processes engaged, viz. (1) mechanical, (2) biological, and (3) chemical; and although the result is the same, viz., the conversion of complex organic compounds into simpler ones, it is difficult to apportion the exact share which each takes in producing the final result. In the first place, there is the mechanical cleansing of the water from the coarser impurities by the filter. This is self-evident, and needs no explanation. Naturally, the finer the material in the filter, and the thicker the layer through which the water has to pass, the more effectual this will be. The next process, the biological, also takes place in the filter and is probably due to the activity of anaërobic organisms in its interstices. These organisms assist in splitting up the complex organic matters mentioned through their various stages, viz., ammonia and nitrites, into the end products known as nitrates. The periodical cleansing of this filter by "live" steam, no doubt, puts a temporary check on this action, but when the water is put through the filter again, the spar will soon regain a fresh supply of anaërobes. The third cleansing process (chemical) is that due to the exposure of the water to the atmosphere by the aërator on the roof. This is principally one of oxidation, in which the greater portion of the organic matter will be destroyed by the combination of the atmospheric oxygen with it, the final products being water, carbonic acid, and an innocuous residue. Saline ammonia and any volatile animal products in the water will also be got rid of during this process of aëration. This, no one who takes the trouble to visit the aërator can doubt, for the sense of smell will convince him that a number of such products are freely given off.

The following is a description of the working of the scheme :—The water is first put into the first- and second-class baths direct from the main, and then alternately allowed to gravitate to a strainer, which eliminates such solid particles as portions of bathing costumes, grit, hair-pins, &c., &c. The water is afterwards raised by pumps to the aërating tower, which is fixed on the roof, by which means the whole of the water is broken up and exposed to the atmosphere, and thus it receives a fresh supply of oxygen. The water then descends and passes through the filter, which purifies it. Then it passes through a heater, which is worked by the spent steam from the pumps and from other parts of the building, producing a temperature of 74° Fahr., and after this, the water is delivered into the shallow end of the bath, again fit for bathing. This process is continuous. The filter is cleansed about every second or third day, by passing about 2,000 gallons of water and live steam the reverse way through the filtering media, and washing the accumulation out into the sewer. The first- and second-class baths are worked alternately, and the plant will deal with 20,000 gallons per hour; the water in the large swim being changed every four-and-a half hours by this process of circulation. As the baths are situated near manufacturing works, there is a tendency for dust to blow in through the louvre ventilators during the night, and settle on the water; therefore a spray is used each morning to clean off the top surface, and it also replenishes any water lost by evaporation and that used in the emptying of the filtering chamber during the periods of cleansing.

The various parts consist of (1) A strainer

to intercept particles likely to obstruct the pumps. (2) Two pumps to deliver the water to the aërator. (3) An aërator to oxygenate the water, situated on the roof. (4) A filter capable of filtering the water, provided with means of cleansing the filtering surface when required. (5) A heater-condenser capable of condensing the steam used by the pump, and of raising the temperature of the water from about 50° to 74° F., when supplied with auxiliary live steam.

Aërator.—The aërator consists of cast-iron "A" frames supporting a copper perforated

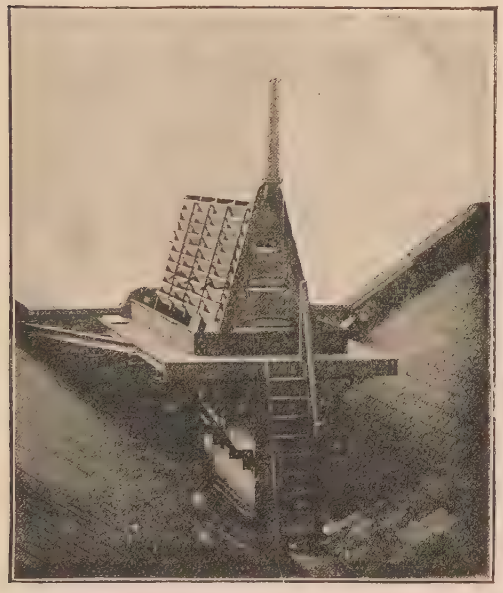


Fig. 4.—Aërator.

pipe. These "A" frames are connected together by means of light girders at intervals, and fixed to these girders are perforated zinc trays, having sufficient number of perforations to allow the required amount of water to pass through in a large number of very fine streams. The aërator is fitted with three of these trays. The bottom of the aërator consists of a galvanized sheet-iron tank to receive the aërated water. The end frames of the aërator are boarded in, and the sides are fitted with a number of louvre boards, so arranged that the air can have free inlet and outlet to the water, and that any water splashing on to these boards will run back again into the tank. Rough plate glass is now being substituted for wood in the louvres, so as to admit more light to the water.

Filter.—The filter measures 14 ft. by 6 ft. 6 in. by 5 ft. 6 in. deep, and is of sufficient surface to deal with 20,000 gallons of water per hour. The filter tank consists of cast-iron plates. The filter is arranged inside with a rib which supports a couple of filter plates of wrought iron, these filter plates having a sheet of wire gauze in between, and so arranged that the holes in the plates are opposite one another. In that part of the filter below the filter plates a cast-iron pipe is connected to a valve on the outside of the filter. This cast-iron pipe has a large number of 1½ in. wrought-iron pipes branching out under the whole of the filter surface, these pipes having a number of very small holes arranged in them, so that the delivery of air for flushing purposes may be distributed as evenly as possible on to the surface of the filtering material. The filtering material consists of gravel of special quality, about 18 in. or 19 in. deep, supported on the above-mentioned plates. The cost of the plant and builders' work was £965; at present the scheme shows a saving of £188 5*s.* 4*d.* on the year's working. R. J. A.

Bell's Water Filters.—(*See* "Mechanical Filtration.")

Benching.—A raised step at the bottom of a manhole so formed that any liquids falling on same may flow off into the drain.

Boilers.—A satisfactory steam power plant must, in addition to having an efficient engine, also have an economical *boiler*, the design and setting of which should be such as to use the heat generated to the best possible advantage with a minimum cost for fuel. Different types of boilers are required for different powers and conditions of working, and it is necessary to investigate boiler efficiency as distinct from that of the engine

in order to allocate to the proper quarter any wastes taking place. The principal types of boiler in use are the Cornish, the Lancashire, the Galloway, the Babcock and Wilcox, and other forms of water-tube boilers. In the *Cornish* boiler there is one central flue containing the furnace, with side-flues and bottom-flue. This type works at a pressure of about 80 lbs. per square inch, is only suited for comparatively small powers ranging from 40 to 150 h.p., and is made from 4 ft. to 6 ft. 6 in. diameter. The *Lancashire* boiler is similar to the Cornish in general arrangement and setting, but has the distinguishing feature of two central flues instead of one. These boilers are made in sizes varying from about 80 h.p. (14 ft. by 5 ft. 6 in.) to 390 h.p. (30 ft. by 8 ft. 6 in.), and for working pressures up to 160 lbs. to the square inch. Lancashire boilers are steady steam producers, have a large water capacity, and are easily accessible. For ordinary waterworks pumping purposes and for other general use it is the most serviceable and economical form that can be used. *Galloway* boilers have two circular furnaces, extending about one-third the length of the boiler, and which open into a wide flue, in which are inserted Galloway tubes. Pockets placed at each side of the wide flue just beyond the furnaces contract the area and divert the furnace flames towards the centre tubes. These boilers have evaporated over 12 lbs. of water per pound of coal. *Water-tube* boilers are usually classed in two main divisions, viz., those with large tubes and those with small tubes. The Babcock and Wilcox boiler, with inclined tubes connected into headers at each end, and these in turn communicating with the steam drum, is an example of the first division, whilst the Yarrow and the Thornycroft boilers, having a number of small tubes communicating with upper and lower drums are examples of the second class. Water-tube boilers have a small water capacity, are quick steaming, give systematic circulation of water, are light and portable, and are suitable for the quick generation of high pressure steam. Their disadvantages are liability to smoke with bituminous coals, smallness of thermal capacity and unsteadiness of steaming, increased complication and cost of repairs, and the necessity of using pure water to avoid incrustation of the tubes.

Boiler Efficiency.—The weight of water evaporated by a boiler from a given temperature per pound of fuel used is in practice taken to represent the efficiency of the boiler in the same way that the weight of steam used by an engine per i.h.p. hour is regarded as the measure of its efficiency. A more accurate statement of the efficiency of the boiler is made by separately calculating the heat units given to the water and the heat units obtained by the combustion of 1 lb. of coal, so that the ratio,

$$\frac{\text{Heat units given to the water}}{\text{Heat units from coal}} = \text{the boiler efficiency.}$$

A much higher percentage of efficiency may be obtained from a good boiler properly set and fired, than from the steam engine. A boiler when worked with the best fuel under the best conditions will deliver to the engine as much as 75 % of the theoretical heat of the coal. The combustion of a pound of pure carbon yields 14,500 heat units, which, if fully used, will evaporate into steam at atmospheric pressure 15 lbs. of water from 212° F. In practice, the evaporations of boilers range from about 7 lbs. up to about 13 lbs. of water per pound of combustible according to the type, arrangement, and efficiency of the boiler and furnace and the quality of the coal. An average evaporation of 10 lbs. of water per pound of coal is ordinarily considered a satisfactory result. In addition to the ordinary Lancashire boilers, others giving first-class evaporative results are, the Galloway breeches boiler, the Babcock and Wilcox water-tube, and the Climax water-tube boiler. In seeking economical results in a steam generating plant it must be remembered that such a plant consists of two parts, the furnace and the boiler, each of which must efficiently perform its share of the work. The function of the

furnace is to properly consume the fuel and to procure the greatest amount of heat from a given weight consumed. The function of the boiler is to utilise the fullest possible quantity of heat thus generated in the furnace and to transfer the same into useful effect by evaporating the maximum possible of water into steam. W. H. M.

Boning Rods.—A set of boning rods consists of three exactly similar T-shaped wooden frames. Boning rods are used by drain layers, paviours, and other workmen in performing simple levelling operations, such as setting out a level line, extending a gradient, or ascertaining the intermediate levels between two points. To set out a level, one boning rod is erected at the starting point and another some feet away from it and a straight edge laid across their tops; the second boning rod is raised or lowered until a spirit level, placed at the centre of the straightedge shows it to be exactly horizontal. A third boning rod is set up at an equal distance from the second and the process repeated, except that the straightedge should be reversed. The second boning rod (No. 2) may now be removed; Nos. 1 and 3 will be truly level as any error in the straightedge or spirit level will have been neutralised. A gradient can be set out by first obtaining a level line and then raising or lowering the third rod to the required distance. A line can be extended by sighting across the tops of two boning rods and raising or lowering a third until the tops of all three are exactly in line. Similarly, intermediate levels may be determined by placing boning rods on the outside points and sighting on to a third one between them.

In actual work pegs are driven into the ground for the rods to rest upon and obviously the height of these pegs will indicate the variation of the ground surface. (*See* "Levelling, General Principles of.") E. L. B.

Borewells.—Bored steel-lined tube wells are now very largely employed for access to underground water for public supply and also for numerous trade purposes. Given average success, water obtained in this way commonly costs from 3*d*. to 4*d*. per 1,000 gallons inclusive of interest on capital and working expenses. Unless the water-bearing capacity of a district has been well tested by previous borings, the initial steps towards obtaining underground water is necessarily accompanied by considerable risk, as, although the geological features

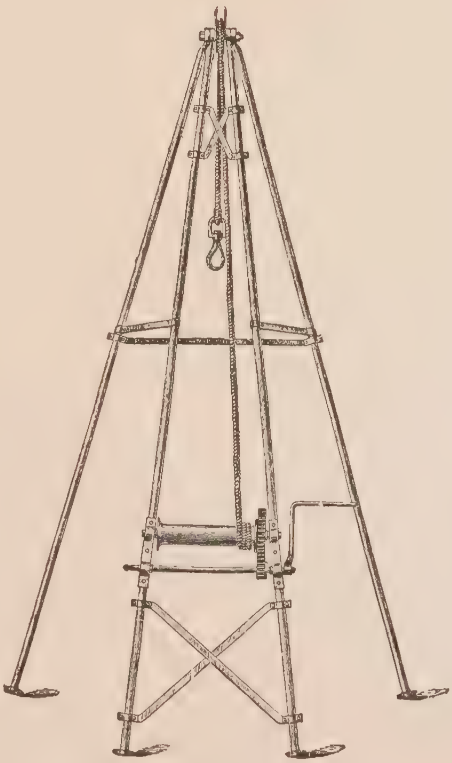


Fig. 1.—Drilling Apparatus.

may seem favourable, nothing short of the expenditure of the necessary money of sinking a fair-sized trial boring, followed by continued pumping operations, can be relied upon. Great improvements have been made of recent years for expeditiously sinking borings of this character. They are now made almost exclusively by percussive mechanism with the aid of a great variety of ingeniously contrived tools adapted for piercing the various classes of strata met with. A typical modern surface plant, as used by the well-known firm of

C. Isler & Co., for raising and lowering the tools in the boring is shown in Fig. 1. It consists of wrought-iron tubular sheer legs and winch, and is well adapted for expeditious sinking and convenient of transport. Steam-winch may also be fitted.

A considerable variety of tools are employed in connection with such a plant for the purpose of meeting the various emergencies of the work as they arise. The principal of these, as illustrated in Fig. 2, are:—

1. Clams for suspending and screwing tubes.
2. Worm auger for loosening compact soils.
3. Clay auger.
4 & 5. Flat chisel for rocky and hard strata.
6. Auger nose shell for bringing soils broken up by the chisel.
7. Flat bottom shell for sandy soil.
8. Shoe-nose shell.
9. Latch tool for picking up pipes from a bore-hole.
10. Spring dart for same purpose.
11. Bell screw for cutting thread on rods broken in bore-hole.
12. Bell box for picking up rods in case of breakage.
13. Spiral worm for extracting broken rods, &c.
14. Swivel rod.
15. Crow's foot for extracting broken rods.
16. Rod joints.
17. Spiral worm for extracting rods.
18. V-chisel for rocky strata, &c.
19. T-chisel for ditto.
20. Rimer for enlarging bore-hole.
21. Lifting-dogs for raising rods.
22. A and B, rod tillers for working rods.
23. Hand dogs for screwing rods.
24. Spring hook.
25. Boring rod with screwed ends.

A complete set of tools for boring to 400 ft. deep, with wrought-iron sheer legs, fitted with the necessary gearing and fast and loose pulleys, costs about £150.

Drilling through sand, gravel, clay or soft rocks is also very expeditiously done by what is known as the *hydraulic washing* system in which the boring rods and chisel are hollow to enable water to be pumped downwards through them, which has the effect of washing all *débris* to the surface, thus obviating the necessity of removing the tools from time to time to the surface, for clearing, &c. The rods and chisels are lifted and dropped as in the ordinary percussion system, the water being forced down at the same time. In suitable soils this is one of the most efficient

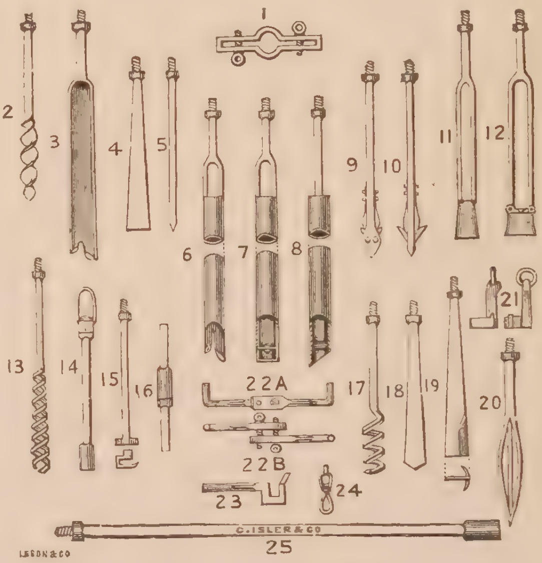


FIG. 2.—Drilling Tools.

and expeditious methods available. Boring through rocks or solid formations is more advantageously done by means of the *Rotary Shot Boring gear* shown in Fig. 3, which has been designed to replace the more costly method of diamond rock drills. The shot is fed into the hollow boring rods and carried downwards by means of water, past the core, and eventually under the crown. The system is suited for the penetration of the hardest rocks. The cost of boring depends largely upon the depth and character of the strata to be passed through, but in gravel, clay, chalk or other soft strata for depths not exceeding 500 ft. the price may lie between 30*s*. and 60*s*. per foot according to circumstances. In rock similar work may cost from 40*s*. to 80*s*.

per foot, for borings not exceeding 12 in. in diameter, and exclusive of lining tubes. Where lining of the bore is necessary wrought-iron lap-welded steel-socketed tubes are used, the approximate prices of which are 6 in. internal diameter 10*s.* per foot, 8½ in. diameter 17*s.* per foot, and 11½ in. diameter 25*s.* per foot.

Other well-known methods of boring which have been successfully employed are the Kind-Chaudron deep-boring system, the Dru deep-boring system, Mather & Platt's system, the American rope-boring system, and deep-boring by diamond drills. The water from borewells is raised either by means of an "air-lift" or by the employment of steam-driven deep-well pumps of the ordinary type. For further information, *see also* articles, "Wells, Artesian Wells, Abyssinian Wells, Underground Water, and Air-lift." W. H. M.

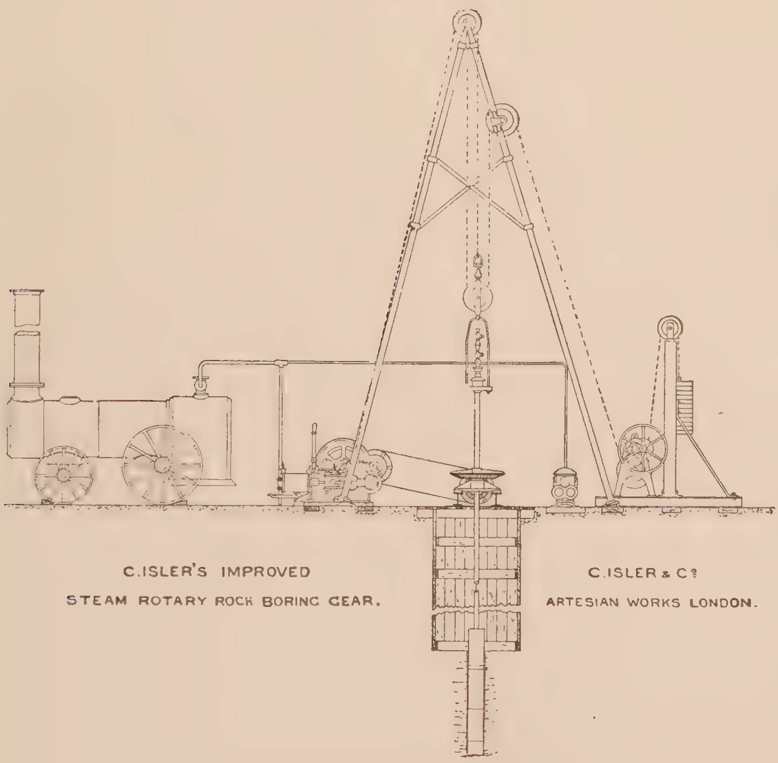


Fig. 3.—Drilling Process in operation.

Boston, U.S.A., Sewage Disposal at.—Boston, Massachusetts, U.S.A., is a city of somewhat over half a million inhabitants, situated at the upper end of an elliptical harbour, about twelve miles long and six miles wide. A considerable number of smaller cities and towns are clustered thickly about the larger municipality, making the population of Greater Boston about 1,250,000. The metropolitan district as a whole covers an area of nearly two hundred miles; and it is intersected by three rivers, the Mystic and the Charles, which discharge at the upper (N.W.) extremity of the harbour, and the Neponset, which enters on its south-westerly side. Originally the sewers of the city discharged at various points (seventy or more) along the water front. At times of heavy rain coinciding with high tides the sewage backed up, and created objectionable conditions in the lower part of the city; and at almost all times there was a serious nuisance in the inner harbour, as the sewage was borne back and forth by the tide. In 1875 a joint engineering and medical commission made a study of the problem and recommended the construction of two main systems of intercepting sewers, one for the region south of the Charles river, including most of Boston proper, and the other for the cities and towns north of the Charles. The development of the former plan, the Boston Main Drainage Works, was begun almost at once, in 1877, and was completed in its general outlines by 1884. The main outfall sewer for this district discharges at Moon Island, near the middle of the harbour. The construction of the Main Drainage Works

has been carried out under successive city engineers, J. P. Davis, H. M. Wightman and William Jackson; Eliot C. Clarke was principal assistant engineer in charge of construction up to 1884. Meanwhile the State Legislature of Massachusetts appointed various commissions to consider the wider problems involved, notably the Metropolitan Drainage Commission of 1881 and the Massachusetts Drainage Commissions of 1884 and 1885. In 1889 the State Board of Health prepared a general plan for a system of intercepting sewers to serve the region north of the Charles, and to discharge at Deer Island at the mouth of the harbour. A special board of Metropolitan Sewerage Commissioners (Hosea Kingman, Chairman) was created by the State Legislature to construct and operate the works, outside of the Boston Drainage District, the costs being apportioned on the several communities involved. Howard A. Carson was Chief Engineer to 1895; William M. Brown has had entire charge of construction and maintenance since that date. The Commission constructed first an intercepting sewer along the south bank of the Charles for the region to the west of Boston. This entered into the Boston Main Drainage system from 1892 to 1904; and the sewage thence passed to Moon Island. The North Metropolitan system for the cities and towns north of the Charles River was essentially completed in 1895; and has since discharged at Deer Island. In 1895 a sewer was begun in the Neponset Valley; and in 1899 construction was begun on a general high-level system for the communities to the south and west of Boston. This system was completed in 1904. It takes most of the sewage which originally passed from the Metropolitan sewer on the south bank of the Charles into the Boston Main Drainage Works, and carries it round the south side of the harbour to discharge at Nut Island near the harbour mouth. The entire system thus includes three main divisions—the North Metropolitan sewer, discharging at Deer Island; the Boston Main Drainage Works, discharging at Moon Island; and the South Metropolitan high-level sewer, discharging at Nut Island.

The North Metropolitan sewer serves certain areas of Boston, and the cities and towns of Winthrop, Chelsea, Everett, Malden, Melrose, Cambridge, Somerville, Medford, Winchester, Woburn, Stoneham, Arlington, Belmont, Wakefield, Lexington and Revere. The total area is 90·50 square miles and the total population January 1, 1908, was estimated at 498,640. Of this population 422,065 are estimated as contributing sewage. The mileage of local sewers connected January 1, 1908, was 624·74, and the number of connections 65,786. The total flow of sewage in 1907 averaged 64,300,000 gallons per day. In constructing the North Metropolitan system, it seemed best, in order to avoid deep excavation in unfavourable ground, to provide for pumping several times with low lifts at each station. The system has three main branches extending to the northern, western, and southern portions of the area. The sewage from the western portion (4,000,000 gallons per day) is lifted 13½ ft. at Alewife Brook, and that from the southerly portion (32,000,000 gallons per day) is lifted about 10 ft. At East Boston, and again at Deer Island, nearly the entire volume of the sewage is pumped, the lift being 15 ft. at the first station and 6 to 15 ft., according to tide, at the second. The equipment at the last two stations consists in each case of three submerged centrifugal pumps with impellers 8·25 ft. in diameter driven by triple-expansion Reynolds-Corliss engines. The cost of pumping is $·1079 per million foot-gallons at Deer Island, and $·0718 at East Boston. Between these two pumping stations the sewage passes in an 8·5-ft. inverted siphon of steel, 264 ft. long, under Shirley Gut. After pumping at Deer Island the sewage is disposed of by continuous underwater discharge through a 6¼-ft. outfall sewer of concrete and brick. The point of discharge is 1,860 ft. out from the shore line at high water, and in a powerful current setting in and out through the mouth of the harbour. Engineering problems of considerable interest

arose in the construction and laying of the Shirley Gut siphon and the outfall sewer. Screening, carried out at the various pumping stations of the North Metropolitan system, intercepted in 1907 rags, paper, &c., to the amount of 2422·2 cu. yds. or 2·8 cu. ft. per million gallons of sewage.

The high-level sewer of the South Metropolitan system now serves about a quarter of the city of Boston and the cities and towns of Brookline, Newton, Watertown, Waltham, Milton, Hyde Park, Dedham, and Quincy. The total area included is 102 square miles, and the population, January 1, 1908, was estimated at 325,090. Of this population 188,150 are estimated as now contributing sewage. The mileage of local sewers connected was 479·51, and the number of connections, 26,019 on January 1, 1908. The total flow of sewage for 1907 averaged 40,600,000 gallons per day.

The sewage from the northern part of the high-level system, amounting to 23,000,000 gallons a day, is pumped at Ward Street, the lift being about 40 ft. The pumps are of reciprocating type with plungers 48 in. in diameter and a 60-in. stroke, operated by vertical triple-expansion Allis-Chalmers engines. From Ward Street the sewage flows by gravity to the outfall at Nut Island. The flow from the southern and eastern part of the district enters for the most part by gravity, although about 3,000,000 gallons a day are pumped at Quincy. The main outfall sewer is 11 ft. 3 in. by 12 ft. 6 in., and it discharges off Nut Island by two 60-in. cast-iron pipes, having an aggregate length of 10,844 ft., and laid under the bed of the harbour. Screens are located at the pumping stations and at Nut Island, and the total screenings removed in 1907 amounted to 2735·6 cu. yds., or 5·0 cu. ft. per million gallons of sewage. The screens at Nut Island are four in number, two in each duplicate channel of the screen room. They are about 12 ft. square with clear openings of $\frac{3}{4}$ in. between the bars, and are operated by small reversing engines.

The third and central system of the three which discharge into Boston Harbour, is the Boston Main Drainage Works, which serves the central portion of the city itself (E. S. Dorr, Chief Engineer). The area is small, only about 13 square miles. The population in this area, however, was estimated at 358,372, January 1, 1908, and practically all of the houses are connected. There are 530·48 miles of local sewers connected with this system. The number of individual connections is not accurately known, but may be placed somewhere between 35,000 and 40,000. The average daily flow of sewage in 1907 was 87,660,000 gallons.

The figures for the whole city of Boston, including the sewers which discharge through the North and the high-level systems as well as the Boston Main Drainage Works, are as follows:—Population, January 1, 1908, 614,632; total area, 42·5 square miles; total length of sewers, 729·26 miles; average flow of sewage, 124,200,000 gallons per day.

The sewage of the Boston Main Drainage Works flows by gravity to the Calf Pasture in Dorchester. At the Calf Pasture it is lifted 36·5 ft. and discharged through a tunnel under Dorchester Bay to the main outfall sewer on Moon Island. Here, as Moon Island is situated near the centre of the harbour and not, like Deer Island and Nut Island, in strong currents of deep water, the sewage is stored in masonry tanks and discharged only on the out-going tide. Before pumping the sewage is screened by passing it through iron cages working in vertical shafts. The screenings removed in 1907 amounted to 577 tons. After pumping, and before entering the tunnel, the sewage passes through two deposit sewers, 8 ft. wide and 16 ft. high, which run side by side for a distance of 1,260 ft., terminating in each case with a dam which keeps a level high enough to ensure a current velocity not exceeding 1 ft. per second. The deposits are moved by a travelling scraping and flushing machine, operated by the current, and are delivered to a sludge tank from which the liquid flows back into the sewer. The sludge removed from the tank is towed out to sea by

scows. It ordinarily amounts to 10,000 cu. yds. per year or 4·5 cu. yds. per million gallons of sewage.

The pumping station is equipped with three high-duty engines, two of which are compound engines, the plungers of which are 48 in. in diameter, with a 9-ft. stroke and a nominal capacity of 35,000,000 gallons a day. The third is a triple-expansion engine, the plungers of which are 60 in. in diameter, with a 10-ft. stroke and a capacity of 72,000 gallons a day with seventeen revolutions per minute. There are also two low-duty engines with 45-in. plungers and a 4-ft. stroke. The nominal capacity of each engine is 25,000,000 gallons a day. The tunnel under Dorchester Bay, between the deposit sewer and the outfall sewer, is of brick, 7,160 ft. long, and it has an inside diameter of 7·5 ft. The outfall sewer itself is 5,900 ft. long, and of horse-shoe section, 11 ft. high and 12 ft. wide. The tanks in which the sewage is stored at Moon Island are four in number, and cover an area of about 10 acres. Their bottoms are of concrete, and their walls of granite blocks, laid in cement. The total capacity of the four tanks is about 50,000,000 gallons. They can be flushed out by introducing sewage under high velocity at either end of the tanks. Along the nearer end of the tanks run two sewers, one above the other, the upper being the sewer which discharges sewage into the tanks; the lower, the one which empties the tanks into the bay. There are two sets of gates for filling and emptying and flushing the tanks; one set is controlled by electro-pneumatic switches, operated by compressed air, and the other set is controlled by a line of shafting. The whole system is driven by a turbine run by the sewage flow. The method of operation is to allow the reservoirs to fill for ten hours and to discharge during the second and third hours of the outgoing tide. The total amount of sewage discharged into Boston Harbour from the three main outlets averaged, in 1907, 192,500,000 gallons a day. The sewage of the Boston Main Drainage Works is studied daily at the Sewage Experiment Station of the Massachusetts Institute of Technology. The following table shows the average analyses for 1905—1907.

Composition of Boston Sewage.

parts per million.

Turbidity.	Sediment.	Suspended Solids.		Organic Nitrogen		Free Ammonia.	Oxygen Consumed.*	
		Total.	Fixed.	Total	Dissolved.		Total	Dissolved.
279	121	135	44	9·1	5·8	13·9	56	43

* 30 minutes, 100°.

The general results of this method of disposal have, on the whole, proved fairly satisfactory. The sewage discharged at Moon Island spreads out on the surface (the discharge is 1 ft. above low water), and is very obvious for an hour or two within an area of half a mile or a mile in diameter. Some nuisance is undoubtedly caused to passing vessels, and it is said that real estate in the neighbourhood has been injured in value. The Massachusetts State Board of Health made careful investigations of the condition of the harbour in 1900, and again in 1905, and showed that the chemical and bacteriological evidences of pollution were manifest on the out-going tide only in a narrow path extending for two miles and a half from Moon Island, and on the incoming tide, only in the immediate vicinity of the outfall itself. At Deer Island and Nut Island where discharge is continuous, under water, and in a strong current, conditions are better. In 1907 the Board of Health pointed out that the most serious pollution of Boston Harbour at present is not at the main outlets at all, but in the upper portion of the harbour, where a considerable amount of sewage still finds its way in by various unauthorised channels.

It is, of course, probable that the concentration of population and the rising level of sanitary standards will ultimately make some other method of disposal desirable, at least for the Moon Island outlet. In view of this contingency the Sewage Experiment Station of the Massachusetts Institute of

Technology has for six years been carrying on experimental studies of the purification of Boston sewage with the following general results. The most suitable method for purifying the sewage from the city proper would be by filtration through trickling or percolating beds. These should be 8 ft. deep and constructed of 1½ in. to 2 in. stone. They might conveniently be located on Thompson's Island near the present Moon Island outfall and would occupy an area of 50 acres. It seems from the experiments so far conducted that it would be more economical to apply the sewage directly to the beds without septic treatment, removing only screenings and heavy detritus. After filtration the trickling effluent must, however, be subjected to a sedimentation of two hours for the removal of suspended solids. At the same time bacterial purification may be attained by disinfection with chloride of lime, using about five parts of available chlorin per million gallons of sewage. Preliminary estimates place the cost of filtration (including capital charges), at about five dollars and a half per million gallons, and the cost of disinfection at about one dollar and a half per million gallons. It is quite possible that the extension of an outfall sewer to the outer harbour with an under-water discharge, preceded by careful screening, might prove more economical and equally satisfactory.

C. E. A. W

Bradford Sewage Disposal. — Population, Area, &c.—The City of Bradford has a population of about 300,000 (1901 census 279,767), the area being 22,800 acres. For sewage disposal purposes, this is divided into ten districts, each having separate sewage disposal works, the most important being at Frizinghall. At the other works the sewage is purified as follows :—

1. *Eccleshall.*—Chemical precipitation and land filtration, 100 acres (clay).

2. *Greengates.* — Chemical precipitation, straining filters (coal), followed by circular filter 7 ft. deep (coal).

3. *Idle.* — Broad irrigation, aluminaferric being added to the sewage.

4. *Heaton.*—Septic tanks and contact beds.

5. *Thornton.*—Chemical precipitation (aluminaferric) and land filtration.

6. *Thackley.*—Broad irrigation.

7. *Sandy Lane.*—Aluminaferric circular precipitation tank, followed by shallow filters (engine ashes).

8. *North Bierley.*—Septic tanks and artificial filters, area six acres, distribution by fixed jets, and also circular distributor 236 ft. diameter.

9. *Lower Wyke.*—Sewage treated by the Brighouse Corporation.

10. *Frizinghall.*—In addition the Corporation of Bradford take and treat the sewage of the Yeadon Urban District. This latter, together with that from Frizinghall and the first named five districts, will be conveyed to the Esholt works, which are being carried out by the Corporation of Bradford at an estimated cost of £1,250,000, including cost of 1,800 acres of land recently purchased.

Volume of Sewage.—The volumes treated at the different works vary, and the trade refuse contained determines the preliminary method of treatment in use.

The largest volume, 13,000,000 gallons a day (dry weather flow) is dealt with at Frizinghall. This sewage comes from the centre of the city, and is more affected by liquid trade refuse than any other. It contains some 6,500,000 gallons of liquids from the processes of wool scouring, dyeing, &c., and in consequence is highly charged with fatty matters and organic matter in solution. The fatty matters brought down in the sewage amount to as much as 25 tons a day. The oxygen absorbed from permanganate in four hours at 80° F. is about 20, and the albuminoid nitrogen 3 parts per 100,000.

Treatment.—The sewage is passed through detritus tanks which remove 10 tons per day of heavy matter, and through screens, each consisting of six sets of tynes set in a common shaft, and caused to revolve in the sewage, and provided with an automatic

cleaning device. Sulphuric acid is then added to the sewage in such quantities as to give an excess of about 5 parts per 100,000 of free sulphuric acid. In this way the sludge is precipitated, being deposited in settling tanks worked in series on the continuous flow system. The sludge produced contains an average of 78% of moisture, and 7% of fatty matter.

Sludge.—The sludge is raised by compressed air into the sludge pressing houses, where it is screened, acidified with sulphuric acid, heated to 100° C by exhaust steam in open vats, and then passed through sludge "rams" into 64 filter presses. The presses are heated by steam, and the whole kept hot during the process of filter pressing. In this way the fatty matters are kept fluid, and pass away from the presses with the press liquor. The resulting cake contains 27% of moisture, and is sold for manure at 3*s.* 6*d.* per ton f.o.r., or used for fuel on the works. The fatty matter is separated from the water, purified, and sold.

Tank Effluent.—The effluent water from the precipitation tanks, which is acid in reaction, is at present run off into the river. The high content of soluble organic matter in this effluent is now the difficulty to contend with.

Filtration.—With regard to filtration, the methods at present in use at the Frizinghall works, and which are necessarily only of an experimental character, are the result of the work of several years. A large amount of experimental work has been done, the work including researches on the effect of filtration of (*a*) acid tank effluent (as discharged from the tanks); (*b*) tank effluent neutralised with lime, magnesium, barium salts, &c.; (*c*) tank effluent made slightly alkaline; (*d*) tank effluent after a secondary precipitation; (*e*) septic tank effluents; (*f*) tank effluent containing a large quantity of added sulphuric acid.

The different kinds of material tried have been very numerous, amongst others tried being coal, coke, cinders, shingle, and soil. The depths of the beds varied from 12 in. to 7 ft. 6 in.

Any work on the purification of the Bradford effluent must be judged from the standpoint of the high content of soluble organic matter in the tank effluent. The results obtained prove that the Bradford effluent can be efficiently purified notwithstanding the acidity, and they further prove that the acidity of a tank effluent has no very marked detrimental effect on the purification effected in a filter bed. In confirmation of this fact, which is quite contrary to the view of most authorities to-day, two series of experiments were carried out. In the first, two filters of similar material were worked side by side under the same conditions, one filter treating acid tank effluent, and the other treating similar effluent, which had been neutralised with lime. An average of 111 analyses made of each effluent showed a difference of only 0·11 parts per 100,000 of oxygen absorbed in favour of the filter treating neutral effluent. In the second series, a filter of cinders was supplied with tank effluent containing added sulphuric acid varying in amount from 25 to 60 parts per 100,000. The filter was worked for several months, and notwithstanding the very large amount of acid, satisfactory results were obtained. A large portion of the acid was neutralised in the bed, the acidity of the filter effluent varying between 7 and 29 parts per 100,000. The oxygen absorbed figure was rather higher and the albuminoid ammonia figure always lower than in ordinary filter effluents. As regards the question of nitrification, the Frizinghall analyses show that with the exception of one set of experiments in 1906–7, nitrification does not take place unless the acidity of the tank effluent is neutralised in the bed. In the experiments referred to, the effluent was one from a coal bed, and in the average of over 180 analyses, although the effluent showed a slight acid reaction, the nitrates averaged between ·1 and 1·5 parts per 100,000.

Bacteriological Work.—During the last 18 months bacteriological investigations have

been made at Frizinghall on the crude sewage and effluents. The chief result of the work so far has been to show that the effluents from the filtration of Bradford sewage can be brought to the provisional standards suggested by Dr. Houston in the Second Report of the Royal Commission on Sewage Disposal.

Summary.—On the basis of the experimental work done at Frizinghall, therefore, it is held that the acidity of a tank effluent does not exert any marked detrimental action on its subsequent filtration, either chemically or biologically ; nitrates, however, are not formed, and their absence points to the fact that nitrification is not essential to the efficient purification of this sewage. The researches are being continued, and the bacteriological aspect of the question more thoroughly investigated. The new sewage works at Esholt necessitate the construction of an outfall sewer nearly 3½ miles long and 10 ft. diameter, constructed in tunnel for a continuous length of 2¾ miles. Also an intercepting sewer 1¾ miles long, chiefly egg-shaped in cross section 3 ft. 6 in. by 2 ft. 6 in., constructed in tunnel for one-third of a mile, and a pumping plant capable of raising 2,000,000 gallons per day to a height of 120 ft. At the Esholt end of the tunnel the sewage will be delivered into detritus tanks of 1,000,000 gallons capacity, screened, mixed with acid, and passed into precipitation tanks of 19,500,000 gallons capacity, arranged with two divisions so that a second dose of chemicals can be added if necessary. The tank effluent water will then be passed on to 60 acres of filters 6 ft. deep, rectangular in plan and arranged in half-acre beds, and on to 411 acres of land laid out for filtration purposes. The storm water will be passed through tanks of 11,500,000 gallons capacity, and on to 50 acres of land. The buildings and works necessary for the treatment of sludge will cover an area of about 3½ acres. The minimum volume of sewage to be dealt with is 15,000,000 gallons per day.

J. G.

Brazing.—(*See* "Plumbing.")

Bricks and Brickwork for Sewers.—The best materials procurable at a reasonable cost should be used in the construction of sewers, as it is most necessary that they should be constructed and remain watertight; be capable of resisting the crushing pressure exerted by the superincumbent earth, and withstand the erosion caused by the sand and pebbles being carried along the invert, in addition to being unaffected either by the sewer-gas or the chemicals present in the sewage of manufacturing towns. Bricks for sewers may be either wire-cut or pressed, the former being commonly used for the crown and the latter for the invert, they should be well burnt in a kiln, uniform in size and shape, with sharp arrises, free from lumps of lime and pebbles and as non-absorbent as possible. They should be comparatively tough and have considerable hardness, while the faces should be true to permit of joints not exceeding $\frac{5}{16}$ in. as a maximum. The colour of the bricks is immaterial, and smoothness of surface is not an essential characteristic except in the invert, provided the excrescences on the exposed face are not sufficiently large to interfere with the flow, as a thin layer of sewage quickly forms a smooth face on the interior of the sewer. The best bricks to use are Blue Staffordshire, Ruabon, or Buckley, which will generally absorb less than 4% of their weight when soaked in water. Gault bricks, although absorbing nearly 20% of water, may be used on account of their hardness and durability provided they are not perforated, or have frogs formed in them, as is frequently done to reduce their weight. Staffordshire brindles, which are an off-product of blue burnings, and are variegated in colour according to their more or less exposed position in the kiln, are also suitable. Broken bricks, burrs, place bricks, grizzles, or chuffs should never be used; soft bricks would quickly wear away. Any individual bricks which do not come up to the standard, if not too numerous, may be used for backing. Bricks for sewer work should be tested for absorption, hardness, crushing, and freedom

from lime. The absorption test which to a certain extent is a general guide to the quality of the brick, can be quickly made as follows:—Thoroughly dry the sample brick, weigh it, place in boiling water and boil for 20 minutes, then allow the brick to cool in the water, and after being carefully wiped dry, weigh it again. Generally speaking, no brick should be used in sewer work which absorbs more than 10% of its weight in water. Another method of testing is to soak the sample brick in a strong solution of sulphuric acid for a few days, when, if no loss of weight occurs and the brick otherwise stands the test, the consignment may safely be used in the construction of the sewers. Brick sewers are usually built either oval or circular, the former section giving a quicker velocity with a small flow than the latter, and usually a better class brick, such as a best pressed blue Staffordshire, is used in the invert. Where bricks of different kinds are used they should all be of the same size to properly bond together. The bricks are laid in 4½ in. rings, of which there should never be less than two, unless the outer part of the sewer is formed of concrete. Cement mortar (1 part cement, 2 sand) should be used for jointing, and the joints should be struck as the work proceeds. Bricks for circular works of less radius than 3 ft. should be specially moulded to the required taper to prevent wide joints on the extrados, and the various sizes should be stamped with a distinguishing mark. H. A.

Broad Irrigation.—(*See* "Sewage Disposal.")

Bryan's Jets.—(*See* "Jets.")

Building Construction in its Sanitary Aspect.—**Walls—Papering—Floors—Windows—Ventilators—Chimney Flues—Cupboards—Partitions—Position of W.C.—Water Supply—Dustbins—Insanitary Conditions.**—The site and aspect of the house demand the first consideration, but these will be dealt with under a separate heading later on. The prevention of damp rising in or penetrating through the walls, or downwards through the roof, will also be dealt with in a special section. Many important details of construction remain which will now be reviewed.

Walls.—Concrete under the footings of the walls is only necessary when the soil is of irregular density or has insufficient supporting power without it, and the foundation is then widened so as to reduce the intensity of the pressure to half a ton or one ton per square foot. Modern bye-laws, however, usually require that not less than 9 in. of concrete shall be placed below the brick footings, extending 6 in. beyond them on each side, irrespective of the soil below, as in Fig. 1. The number of courses in the footings is equal to the number of half bricks, or 4½ in., in the thickness of the wall, each projecting 2¼ in. beyond the course above, so that the bottom course is twice the width of the base of the wall. Brick walls and porous plastering are very beneficial to the health of the inmates of the dwelling; they allow of the passage of a considerable quantity of air without any feeling of draught; they absorb the surplus moisture in the atmosphere of the rooms, and do not allow of condensation on the surface when a rapid rise of temperature takes place, as happens with stone walls, cement plastering, or varnished papers. Stone walls have sometimes a half-brick lining, or a thick coat of plastering, which promotes the dryness of the rooms. Bricks should be hard burnt but not too dense, and should not be glazed except where they require occasional cleansing, or are used to reflect light. In poor neighbourhoods the external walls at the back of the premises should be lime-washed every twelve months, and all sculleries should be washed and distempered at the same time. Limewash is composed of fresh burnt chalk lime, with a little alum in it to prevent it from rubbing off too readily. Internal plastering should be put on in three coats, the first consisting of slaked chalk lime with 1 to 1½ times its bulk of clean sharp sand, and 1 lb. of ox hair to every 2 cu. ft. of "stuff;" this is called the

"pricking up" coat. The second, or "floating" coat, consists of slaked lime with a little white hair added. The third, or "setting" coat, consists of pure slaked lime without hair, and with about 25% of plaster of Paris to expedite the setting and give a slightly harder face. Stone lime, or hydraulic lime, must not be used for plastering as it is apt to contain hard particles, which slake slowly and cause "blowing" or blistering.

Papering.—The most hygienic papers are those known in the trade as "sanitary" papers. They have a smooth surface that does not collect the dust and they may be cleaned with dough or wiped lightly with a damp cloth without injuring the paper. Highly-coloured papers should be avoided, as they may contain arsenic, especially those having bright green in them. Before re-papering a room the old paper should be stripped off and the wall scrubbed down and any damage to the plastering made good. Old houses, especially in poor neighbourhoods, have frequently seven or eight thicknesses of paper on the walls, with the paste in a more or less decomposed state, and the junctions with the mouldings round the doors and windows gaping open and forming a breeding and harbouring place for fleas and bugs.

Floors.—The basement floors of dwelling-houses, and ground floors where there are no basements, are usually of deal battens on fir joists for the living rooms and kitchens, and of concrete and tiles for sculleries, or concrete alone for cellars. The concrete should be composed of 1 part of Portland cement, 2 parts of sand, and 5 or 6 parts of broken stone, hard brick, clinker or flint gravel. Coke breeze is too porus to use for the aggregate in concrete next to the soil. The fir joists are supported on sleeper walls at intervals of 4 to 6 ft. The external walls should have air bricks inserted about every 6 ft. to ventilate the underside of the wooden floor; without this precaution dry rot is very liable to occur. A continuous course of perforated glazed tiles is sometimes adopted for this purpose, but they let in too much air and cause a draught through the joints of the flooring. All floor boards should be well seasoned to prevent shrinkage and a consequent opening of the joints which would let dust through to collect in the space below. Double floors for upper stories, consisting of common bridging joists in one direction upon which the boards are nailed, and ceiling joists in the opposite direction upon which the ceiling laths are nailed, not only make a stiffer floor, but allow the

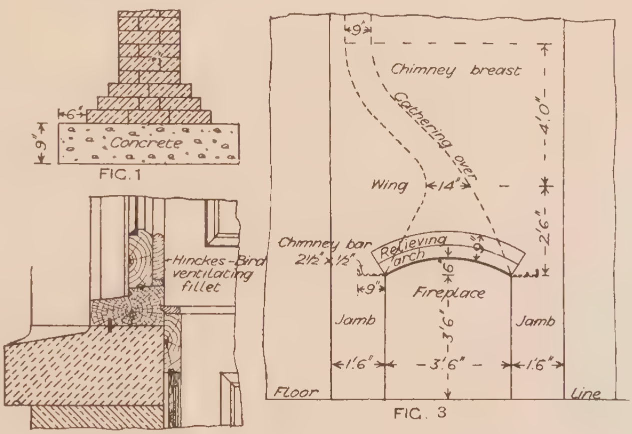


Fig. 1.—Ordinary Foundation to Brick Wall.
,, 2.—Section through Window Sill.
,, 3.—Elevation of Chimney Breast.

air to circulate from air bricks which should be placed in the outer walls. Skirtings should be plastered at the back to obstruct the passage of vermin; this also reduces the risk of fire travelling quickly up a lath and plaster partition. Floors should not be covered with an impervious material, such as oil-cloth or linoleum, unless well ventilated below. Carpets should not extend to the walls, it is much more sanitary if a space of 18 in. all round is left uncovered and stained. The floors of school rooms, hospitals, and public buildings generally, should be formed of hard wood blocks laid on mastic with close joints, so as to leave no crevices for the collection of germs. If these floors are properly prepared

and beeswaxed they will be non-absorbent and readily cleaned. Any floors that are washed should be dried as quickly as possible by free ventilation from open windows.

Windows should bear some proportion to the floor area, height and shape of the room, and various rules are given by different authorities; for example, Sir W. Chambers—breadth of window should be one-eighth of the sum of the breadth and height of room, and height of window 2 to $2\frac{1}{2}$ times its breadth. Joseph Gwilt—1 ft. super of light to every 100 cu. ft. contents of room. Sir Douglas Galton—1 ft. super to every 50 or 55 cu. ft. in hospitals. Robert Morris—area of window surface should equal the square root of the cubic contents of the room. J. S. Adams—width of window should equal the side of a square whose diagonal is the height. A common rule is to make the window area one-eighth to one-tenth of the floor area. The window-sill should be 18 in. to 36 in. above the floor, average 30 in. The head of the window should be carried up as near the ceiling as possible, say within 12 in. of it, and should be made to open. Above the ordinary inside bead along the bottom rail of the lower sash, there should be a piece of wood 3 in. deep, to permit of the bottom sash being raised to that extent without exposing the opening, as in Fig. 2. This permits of free ventilation at the meeting bars without objectionable draught, and is known as the Hinckes-Bird system of ventilation.

Ventilators.—Open fire-places are the best ventilators in a dwelling-house, but these generally require to be supplemented by Arnot valves in the chimney flue or into a separate ventilating flue carried up alongside. Objection is sometimes made to these valves from the dirty stain surrounding them, which is generally alleged to be due to smoke escaping from the chimney, but is really due to the dust in the air impinging upon the wall owing to the momentum of the particles carrying them in straight lines instead of allowing them to deflect with the air current. Rooms without fire-places should have a Sherringham inlet ventilator, Tobin tube, pipe flue, or perforated zinc square from ceiling to roof space. Fire-places should never be closed by a board and the register door of stoves should always be left open.

Chimney Flues should not go straight up but be gathered over the wing in the chimney breast and carried up the side as in Fig. 3. The usual size is 14 in. by 9 in., this being the smallest size the "chimney boys" of the eighteenth century could climb, but 9 in. by 9 in. is sufficient in the majority of cases. A chimney pot on top, of a smaller sectional area than the flue, causes the escaping hot air and gases to leave with a much higher velocity and with little increase of friction, so that there is less tendency to a down draught. Chimney tops should be carried higher than surrounding buildings, or there will always be a tendency to smoke, but a smoky chimney is sometimes due to the want of an inlet for fresh air to the room.

Cupboards should be of dwarf construction, say 3 ft. high, or should be carried up to the ceiling, or a second cupboard fitted above; a cupboard 6 or 8 ft. high leaves a space on top for dust and rubbish to collect.

Partitions.—Lath and plaster partitions are commonly used because they are cheap and can be utilised to support the upper floors, but they are readily attacked and destroyed by fire. A brick-nogged partition, where the spaces between the uprights are filled in with common bricks, is more sound-proof and fire-resisting, and where no superincumbent weight has to be carried the "Mack" partition, of solid porous slabs, is to be recommended.

Position of W.C.—The inside w.c. should always be against an external wall with the soil pipe outside. There should be a window to open, not less than 2 sq. ft. in area, and also an air-brick high up with an ornamental grating inside, which is always open. It is an advantage if the door is at least 1 in. off the floor. If the apartment can be shut off from the house by a lobby with a cross current of air it will keep all smell away

from the house. A w.c. must not be entered direct from any living room or place where food is prepared.

Water Supply.—The service pipes should be laid 2 ft. below the ground to avoid the effects of frost, and in addition to the stop-cock in the foot-path required by the water company, another should be placed immediately inside the house. The supply to the cistern should preferably be carried up an internal wall, but if it must go up on the inside face of an outer wall it should be boxed in, the space being filled up with cocoa-nut fibre. All exposed pipes in the roof should be lapped with gaskin and covered with canvas. Haybands form a cheap substitute. Old carpet used for this purpose simply harbours moth.

Cisterns should not be placed under floors, but in a cistern room in the roof or attics. For moderately hard water, say, over 10 degrees of hardness or grains of lime salts per gallon, they may be of galvanized iron, or of wood lined with lead or zinc, but for soft water they should be of slate with cement joints, not red lead, which is poisonous. A cover should be provided to keep out dust, leaves, birds, beetles, and mice. Some glass slates or a skylight should be provided in the roof and the cistern should be cleaned out at least once a year. Many writers on hygiene say that drinking-water cisterns should be cleaned out every month, but it is really safer to have it done properly once or twice a year, than to have the duty performed oftener in a perfunctory manner. The overflow pipe should be 3 in. from the top and should discharge in the open air, where any leakage would be seen, and not on to a roof to be carried away by the rain water guttering. The w.c.'s must not be flushed direct from the drinking-water cistern, but should have three-gallon waste preventer cisterns fed by a ball cock in each.

Dust Bins.—Fixed dust bins should in no case be allowed, portable covered galvanized iron sanitary bins, holding 2 or 3 cub. ft., should be provided in towns, where they can be emptied weekly by the authorities. In the country the animal and vegetable refuse may be burnt or dug into the garden, and the ashes used for making up paths.

Insanitary Conditions. — The principal sources of unhealthiness in dwellings are: building on made ground, a wet sub-soil, damp walls, rotten floors, insufficient depth below floors, dead vermin, drains untrapped or leaking, want of ventilation, ventilating shafts improperly placed, poisonous wall papers, non-removal of old papers, leakage of gas, broken slates and defective gutters, low ceilings and small windows, fire-place openings closed, flues blocked up, polluted water supply, foul cisterns, non-removal of house refuse, and want of cleanliness. The chief enactments which give public control over these matters are the Public Health Acts, 1875 and 1891, The Housing of the Working Classes Act, 1890, The London Building Act, 1894, and the various bye-laws of the county and district councils. H. A.

Burial Grounds and Cemeteries.—Sanitary Requirements of Cemeteries—Size of Grave Spaces—Purchase of Land for Burial Grounds—Power to Appropriate Land—Disused Burial Grounds—Repairs to Fencing Surrounding Burial Grounds.

Sanitary Requirements of Cemeteries.—In 1888 the Local Government Board issued a "Memorandum on the Sanitary Requirements of Cemeteries." It embodies the views of the official medical advisers of the English Government as to avoidance of dangers to health. It is stated that the soil of a cemetery should be of an open porous nature, with numerous interstices; easily worked, yet not loose; free from water or hard rock to a depth of at least 8 ft., and sufficiently elevated above the drainage level of the locality. Loam and sand are the best; clay and loose stones the worst soils. It may be taken that a distance of 200 yards is amply sufficient to prevent any injury to health from a well-kept cemetery, so far as regards noxious matters transmitted through the air. The

Burial Act of 1855 prescribes 100 yards as the minimum distance between the burial places and human habitations; the Cemeteries Act, 1847, 200 yards. The drainage of a cemetery should not be allowed to enter a stream from which water is drawn for domestic use. The Acts and regulations prescribe no limit of distance for water supplies within which a cemetery is not to be established. There is no power to prevent anyone from sinking a well on his own property, as near to a cemetery as he pleases. The regulations of the Home Office prescribe that no unwalled grave shall be reopened within fourteen years after the burial of a person above twelve years of age, or within eight years after the burial of a child under twelve years of age, unless to bury another member of the same family, in which case a layer of earth, not less than 1 ft. thick, shall be left undisturbed above the previously buried coffin; but if on reopening any grave the soil be found to be offensive, such soil shall not be disturbed, and in no case shall human remains be moved from the grave.

Size of Grave Spaces.—The size of the grave spaces is 9 ft. by 4 ft. = 4 square yards, for an adult; and for a child under twelve 2 square yards, viz.: either 4½ ft. by 4 ft. or 6 ft. by 3 ft. They allow for the hole dug for an adult to be 7 ft. by 2 ft. In any case it is important that each grave should be at least a foot distant from the nearest grave on every side. The minimum allowance of space in a cemetery should be about a quarter of an acre per 1,000 inhabitants. This allows the graves to be re-used every fourteen years.

Purchase of Land for Burial Grounds.—A burial board, with the vestry or vestries of the parish or respective parishes for which the board is appointed to act, may purchase any lands, including, if necessary, any cemetery belonging to any company or persons, or in lieu of providing a burial ground may contract with any company or persons entitled to any cemetery for the interment therein of the bodies of persons who would have had rights of interment in the burial grounds of the parish or parishes for which the burial board acts. No approval, sanction, or authorisation of the vestry is requisite where the town council of a borough, or a local board, or improvement commissioners have been constituted a burial board by Order in Council. Where the vestry refuse or neglect to authorise the necessary expenditure for providing a burial ground and building the necessary chapel or chapels thereon, the Secretary of State may on appeal authorise the expenditure, the borrowing of money for the purpose, the purchase of land, &c., without any further sanction, approval, or authorisation of the vestry. A burial board may lay out and embellish any burial-ground provided by them in such manner as may be fitting and proper, and may build on any land to be purchased or appropriated, according to plans approved by the Bishop of the Diocese, a chapel for the performance of the burial service according to the rites of the Church of England.

Power to Appropriate Land.—A Town Council of any borough may appropriate for the purposes of the Burial Acts any land belonging to the body corporate of the borough, or vested in any trustees, or others for the general use of the borough, or for any specific charity, provided that when any land so appropriated is subject to any charitable use it may be taken only on such conditions as the Chancery Division in the exercise of its jurisdiction over charitable trusts shall direct and appoint.

Disused Burial Grounds.—It is not lawful to build upon any disused burial ground, except for the purpose of enlarging a church, chapel, meeting-house, or other places of worship.

Repairs to Fences Surrounding Burial Grounds.—Any urban authority constituting a burial board may from time to time repair and uphold the fences surrounding any burial ground which has been discontinued as such within their jurisdiction, or they may take down any fences and substitute others in lieu thereof.

A. C. F.

Calorifier. — A chamber having tubes through which steam is projected for the purpose of heating the surrounding water.

Camp Sanitation. — **Camp Site — Camp Space—Water Supply—Kitchens and Ablution Places—Disposal of Excreta.**—All camps may be regarded as hastily constructed towns, in which the tents or huts represent so many houses, while their sanitation depends upon orderly habits governed by corporate and individual discipline. The selection of a camp site is dominated largely by the facilities which exist for obtaining water. This is particularly so in regard to temporary encampments, but where camp sites are likely to be occupied any length of time the feasibility of bringing the water to the camp must be as much considered as taking the camp to the water.

The Camp Site.—The proper location of a camp, as a matter of importance in maintaining the health of the occupants, demands intelligent consideration. It is a good rule to select the site as if for continual occupancy, and, if possible, on high ground, since not only is the surface drainage better, but exposure to air currents facilitates evaporation. Situations at the base of hills are usually damp, and only acceptable if a deep transverse ravine intercepts the drainage from the adjacent high ground. No encampment should be placed in ravines or dry beds of water-courses; similarly valleys and punch-bowl depressions are objectionable. The vicinity of marshes or irrigated lands should be avoided, while localities to which surface or subsoil water gravitates are undesirable for obvious reasons. An abandoned camp site should never be utilised except under circumstances of great necessity—soil contamination is certain, and there is a strong probability of its specific infection. As regards actual soil, it may be said the more porous the better; but if a camp must be located upon an impermeable soil, the area affording the best surface drainage and the least dust should be chosen. Apart from the accessibility to water, the golden rule in the selection of camp sites is—choose areas which are not only dry, but clean, that is, have not been occupied recently for other encampments, and are not fouled or in any way encumbered with the recent filth of man and animals.

The Camp Space.—Owing to physical difficulties connected with the locality, this is subject to variation, but the main principle to be borne in mind is that each tent or hut should be separated from its neighbour by an interval equal to its own height. The risk of camp life, however, lies not so much in excessive density of population on the gross superficies as in overcrowding of individual tents or huts. This is a matter of great difficulty, and often dependent upon financial considerations. So far as possible, each occupant of a tent or hut should be allotted an available space of 20 square feet in order to minimise the facilities for direct infection from man to man which camp life does so much to foster. All tent walls should be looped up daily for at least three hours, and during the absence of the occupants, so that the tent area may be disinfected by fresh air and sunlight. Where huts are used the doors and windows must be opened daily to permit of aëration. In permanent camps all tents should be struck and their enclosed ground area sunned or aired for eight hours every week; if the space permits the tents should be shifted to a new site once a month. The excavating of soil within a tent area should be forbidden as tending to impede ventilation and cleanliness. If floor-boards are not available the ground inside tents may be covered with straw or tarpaulin, but whatever is employed it must be turned out, aired and cleaned daily so long as weather permits. Blankets and bedding must be sunned and aired each day. Whenever possible, special accommodation should be provided in all camps for the eating of meals and the storage of food. The eating, storage or retention of food in the living tents or huts must be discouraged, as the facilities for contamination in these crowded places are great. If food must be retained or stored, every endeavour must be made to keep it in closed tins or boxes so

that flies may not gain access to it. All food remains, particularly if not likely to be utilised in a few hours, should be either burnt or buried.

Water Supply.—The general principles affecting this question need not be considered here except to emphasise the need of scrupulously safeguarding the sources of supply from casual contamination by men or animals. When the circumstances permit, water for animals should be taken at a point distinct from that supplying men; in the case of running water the animal's drinking place must be below that whence the water for men is taken. In camps water is either available from some stand-pipes or from natural source of supply. In each case it is distributed by tanks on wheels or other vessels such as pails, canvas tanks, barrels, or cans. If water is stored in camp the vessels must be protected from dust and other contamination by suitable covers. Individuals should not be allowed to drink direct from the taps of water-tanks, or from the rims or spouts or other receptacles used for carrying or distributing water.

Kitchens and Ablution Places.—The cooking of food in camps presents no serious sanitary problems—at best it must be crude and rough. The most important details which need attention are:—(1) That kitchens be located well away from latrines, urine pits, or other receptacles for refuse and garbage. (2) All sullage water must be made to pass into pits from which it can drain away along suitably dug trenches. This waste water is greasy and, if allowed to pass direct on to soil, soon makes a felt-like scum which attracts flies. A useful procedure is to fill the reception pits or the upper ends of the drainage channels with grass or coarse brushwood. If the greasy water be poured on to this material the grease and other solids are entangled, allowing the clearer liquid to run freely away. The grass, or brushwood, loaded with fatty matter, is conveniently burnt daily and replaced by fresh cuttings. In all camps the system of washing up cooking utensils needs careful supervision, a separate washing-up place being allocated for this purpose. This should be provided with as much boiled or filtered water as circumstances permit. If sand is used for cleaning vessels this should be previously baked over a fire. The whole process of washing up and sand-baking should be under the supervision of a sanitary orderly. The ablution places need to be located conveniently near the tents or huts, and the soiled and soapy water therefrom drained away and disposed of on similar principles to those indicated for kitchen sullage water. In standing camps, unless the physical conditions of the soil and the gradients are distinctly favourable for a rapid absorption and soaking away of all sullage and ablution water, it will be advisable either to shift the location of the kitchen and washing places every few days or to collect this liquid in air-and-water-tight receptacles. Such receptacles should be placed on raised platforms for the better protection of themselves and the ground beneath them, and should be emptied daily and the contents disposed of outside the camp area. Before being returned to use they should be cleaned and smeared over with a cloth soaked in crude creosote oil.

Disposal of Refuse.—Kitchen refuse and the various other items which go to make up the ordinary refuse from camps should never be thrown upon casual ground, but placed invariably in special receptacles conveniently located for the purpose. In temporary camps these receptacles best take the form of pits, but where these are employed the contents must be covered over each day with at least 6 in. of fine earth, the constant endeavour being to protect the material from flies. In more permanent camps all this garbage and refuse should be placed in closed metal receptacles, the contents of which must be removed and disposed of daily. On no account, unless necessity compels, should the solid and liquid refuse be mixed. Carts or vehicles for the removal of refuse to the place of disposal should be of special design and capable of preventing any escape of their contents. The final disposal of this material is often a matter of difficulty. The location of

the place should be always outside the camp area and placed to leeward of prevailing winds, and remote from the kitchens and source of water supply. There are two possible methods of disposal—burial or burning. The former is suitable where the amount of material is not excessive, but when much refuse is present the labour necessary to dig sufficiently large pits is prohibitive. In these cases destruction by fire is the only means of disposal; in fact, it may be said that burning is the ideal mode of disposal in all cases. Theoretically this is so, but practically it is difficult to carry out, mainly on account of the natural dampness of the material. Various portable destructors have been proposed and used, probably the best for fixed encampments is that of Horsfall. In the absence of special destructors much can be done by means of improvised crematories. When crude mineral oil is available its incorporation with the material constitutes an effective aid to its combustion. The construction of a simple grate by laying iron rods or railway rails so as to form a grid or platform, on lateral supports built up of sods or bricks is successful in the combustion of camp refuse—its utility is enhanced if a series be built, arranged concentrically round a central cone of rails or rods stacked or bound together. Cremators of this kind can be built of any size at little cost. One measuring 10 ft. in diameter is capable of burning two tons of damp refuse daily, and, if care be exercised, on to the burning mass the contents of latrine buckets can be thrown and incinerated without local offence. On the same principle a similar crematory can be constructed by lining a circular shallow pit, say 3 ft. deep and 12 ft. in diameter, with large stones, and heaping other stones in the centre to form a pyramid to a height of 6 ft. If ordinary wood be used to start the fire, a freely burning furnace can be maintained by judicious feeding with refuse. Its stones soon become intensely hot, and serve to dispose of liquid and damp material with rapidity. In any devices of this kind the great essential is to secure a draught of air under and through the material to be burnt, and the damper the mass the greater the need of air. An improvised refuse destructor of a simple nature can be made by digging two trenches intersecting at right angles; each trench should be 9 in. deep, and any length from 5 ft. Over the angle of intersection a shaft is built up of sods, a few pieces of iron hooping, or other resistant material, supporting the shaft where it crosses the trenches. A fire can be quickly lighted at the base of the chimney and fed steadily by throwing rubbish down the shaft. Assuming the refuse be added with ordinary care and the potency of the draught trenches maintained by judicious raking, an enormous amount of combustible material can be disposed of in a few hours. Modifications of this type will naturally suggest themselves.

Disposal of Excreta.—This question is vital to the sanitary interests of all, but provided ordinary intelligence be exercised, it presents fewer difficulties than might be expected. The general location of latrines will depend upon the direction of the prevailing wind and the position of the water supply, the rule to be observed being to leeward of the camp and in such a position that no possible fouling of the water supply can result. The construction of these places must not be delayed until tents or huts are fixed, but completed as soon as possible, to safeguard casual fouling of the camp area and its vicinity. Under ordinary circumstances, latrines may be put 100 yards distant from the tents or huts, but always as far as possible away from the kitchens and other places where food is prepared or stored. The extent and type of latrine accommodation in camps will vary according to whether the area is for temporary or permanent occupation. For temporary camps the allowance should be 5 %, and in those intended for long occupation at least 8 %. These figures may be taken to represent either yards or seats, according to circumstances. The multiplication of latrines is undesirable, as one or two fairly large ones are easier of control than several smaller ones, and soil pollution is also more

localised. In permanent camps, latrine accommodation will best take the form of pail-middens with dry earth, fitted with rough wooden seats. For the reception of urine, iron tubs should be provided, these being placed adjacent to the ordinary latrines for day use, and during the night at selected points convenient for the tents. The contents of these several receptacles will need daily removal in covered and water-tight carts to points well away from the camp area, to be disposed of by burial in the earth. If portable middens, such as pails, are not provided, then the seats must be placed over pits or trenches specially dug. Whatever form the latrine takes, its successful conduction depends absolutely upon rigid adherence to the rule that the excreta must be quickly and completely covered over with earth, and this depends, again, upon the enforcement of individual sanitary discipline, adequate *personnel*, and competent administrative control and supervision. For ordinary or more or less temporary camps, the usual latrine is a trench, provided or not with a seat. Some 20 ft. of trench, 2 ft. deep and 16 in. wide, is the common allowance for each hundred persons. For temporary encampments and where the provision of a rough seat is impossible, a preferable arrangement is to provide a series of short trenches in parallel, across which the user straddles; each trench should be 3 ft. long, 1 ft. wide and 2 ft. deep, with the interspace between each trench not more than $2\frac{1}{2}$ ft., preferably less if the soil permits, so as to preclude use otherwise than in the straddling attitude. Every latrine needs to be surrounded by some form of screen, also roofed in if possible, and the soil removed from the trenches must be broken up and carefully piled to the rear, whence it can be scattered as needed over the deposits. All displaced grass sods, too, should be carefully stacked in rear of the loose earth, so that when the trench is filled in these grass sods can be replaced and the soiled area made neat and wholesome. In wet weather, latrines should be protected by a shallow drain to prevent ingress of surface water. So soon as the contents of the trench reach within 6 in. of the top, it should be filled in, the turf replaced and new ground taken up by digging fresh trenches. Some kind of implement, such as a spade, scoop, or tin should be by each trench for replacing earth at each time of use. Kicking the soil in by the foot is certain to be a failure and should be discouraged as conducive to imperfect covering of the excreta and consequent slackness. Notices should be displayed prominently within all latrines impressing upon users the necessity of covering their dejecta before leaving with earth. Failure on their part to adequately cover their excreta should be made a matter of discipline and entail some punishment or disability. If difficulty is experienced in getting this essential act properly carried out, an alternative is to place a man within the screen, provided with a spade, and direct him to cover each deposit with earth as each depositor moves off. A tour of such duty should not exceed two hours, and might well be limited to one hour. A modification of this disciplinary method is to place a sanitary patrol or policeman over the latrine to see that each user thereof fulfils his duty to himself and his neighbour. So long as the sanitary foresight of the masses remains at the present low level, the latrine sentry, however great the sentimental objections may appear, is a necessity, and the only safeguard against fæcal diseases which spread in camps from this point. The care and conduct of latrines in camps must be ever regarded as a disciplinary matter, and unless it is so regarded these places will be the foci of disease in all climates. Consistent practice on the lines explained will result in the latrine being no more offensive than the ordinary ablution place. When this is so, the incidence of filth-originated or dust and fly-borne disease in camps can be reduced to a minimum.

R. H. F.

Candy Mechanical Filter. — (*See* "MECHANICAL FILTRATION.")

Candy Settling Tank. — This consists of a flat-bottomed sewage precipitating tank in which the upward-flow principle has been applied, and which admits of the sludge being removed by the hydrostatic head of water within the tank, the sludge-pipe rising to a level 18 in. below the tank top-water level. The sludge is removed by a revolving perforated sludge-pipe pivoted at the centre of the tank floor. This, together with a rubber squeegee passing over the floor and a similar vertical squeegee for the walls of the tank, is worked by means of a worm-gear at the ground surface level. Hard substances are apt to jam between the squeegee and the floor of the tank, but if the sludge is removed daily the tank on the whole works well, and the growths of bacteria and deposit of sludge on the sides, which cause trouble in the Dortmund tank, are prevented by regularly working the revolving squeegees.

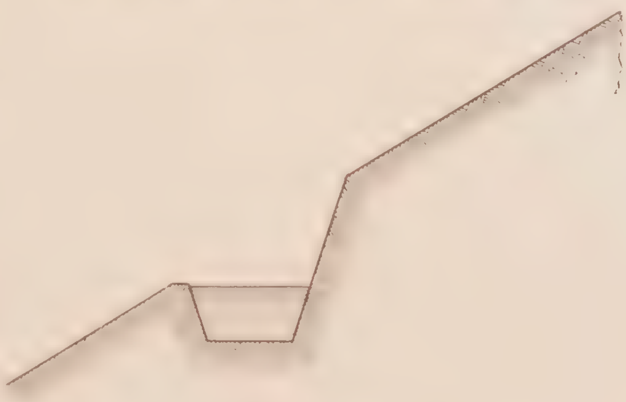
Carbolic Acid, or phenol, C_6H_5OH, is a colourless crystalline solid, very hygroscopic, and having a characteristic odour. It melts at 42° C., boils at 182° C., and has a specific gravity of 1·084 at 0° C. It is not very soluble in water, a saturated solution at 15° C. containing about 5 %, but phenol itself dissolves water, taking up nearly one-fourth its weight at 15° C., forming an oily liquid. The liquefied phenol of the B.P. consists of 100 parts of carbolic acid with 10 parts of water by weight. It has a caustic action on the skin and mucous membrane.

Carbolic acid is produced during the decomposition of a variety of substances; practically all the phenol of commerce is obtained from the distillation of coal. Commercial carbolic acid is a dark oily liquid containing higher homologues and not miscible with water, and requires some 500 times its volume to dissolve it. Until recently it has been widely employed for the preparation of disinfectant fluids and powders, and has the merit of showing no great diminution of germicidal activity in the presence of organic matter either in solution or in suspension. Absolute phenol has been adopted as a standard germicide for the testing of disinfectants. (*See* "DISINFECTION.")

Catch Pits. — Depressions, hollows or sump holes made use of in drainage and sewage disposal works for arresting sand and other such detritus which may pass through drains. The matter to be detained sinks to the bottom of the pits by gravitation, while the liquid and lighter solids of the sewage pass out through the overflow.

Catchment Area.—(*See* "WATER-SHED" and "WATER SUPPLY.")

Catchwater Drain. — Open ditches or catchwater drains are artificially cut along the contour lines of hillside slopes for the purpose of intercepting the flow from rainfall and preventing damage which would otherwise be caused by the water rushing to the foot of the hill-side. The water thus inter-

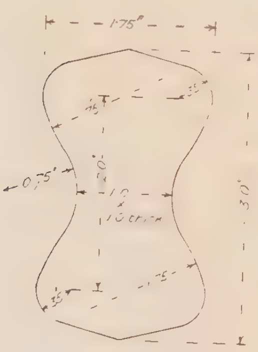


Catchwater Drain.

cepted is passed down from one catchwater drain to another by means of properly constructed conduits of masonry, brickwork, or piping, and so safely conveyed to the required point of discharge.

Cement, Portland.—Portland cement is so called from its resemblance to Portland stone. It is an artificial cement composed

of various ingredients intimately mixed, calcined and ground, finally consisting of about 33 % clay, 63 % lime, 3 % iron, magnesia, &c.; the clay (silicate of alumina) confers the property of hydraulicity. The materials used are chalk and clay by the wet process, and limestone and clay, or shale, by the dry process; the wet process is usually employed on the Thames and Medway. The approximate proportions are 1 of clay to 3 of white chalk or 4 of grey chalk; the quality depends upon the care taken in the manufacture. Under-burning produces a greater bulk from a given quantity of material, and the specific gravity is thereby reduced; less fuel and grinding are required, and a quick setting cement is produced, but it never reaches the same strength as if better burnt. The heavy cements are always slower in setting, but have greater ultimate tensile strength. Light cements may be used for rendering, but a fairly heavy cement is necessary for all work of importance. Over-burnt cement is slow and irregular in setting. Cement which is over-limed expands in setting, that which is over-clayed contracts. The setting of Portland cement is due to the crystallisation of a compound silicate of lime and alumina, together with the evaporation of surplus moisture, and in course of time the formation of a small amount of carbonate of lime by absorption of carbon dioxide from the atmosphere. The specification of weight by Imperial striked bushel is now obsolete, and a specific gravity of 3·1 is required instead, taken with a specific gravity bottle. Of late years cement has been ground much finer than formerly, giving it more covering power and enabling it to take a larger quantity of sand, or, conversely, reach a higher strength. The residue on a sieve $180 \times 180 = 32{,}400$ meshes per sq. in. must not exceed 12 %. The British Standard Specification for Portland Cement revised to June, 1907, is generally adopted. Figure shows the dimensions of a standard briquette. The tensile tests on briquettes 1 sq. in. net section are, 7 days from gauging 400 lbs., 28 days 500 lbs. If the 7-day test comes out higher than 400 lbs., there shall be an increase over 500 lbs. at 28 days, varying from 25 % down to 5 %. Three grades of cement are recognised — "quick-setting," in which the final setting time is not less than 10 nor more than 30 minutes; "medium-setting," in which the time is not less than ½ hour nor more than 1 hour; "slow-setting," in which the time is not less than 2 hours nor more than 7 hours. Final setting occurs when the Vicat needle fails to make an impression. The Le Chatelier test for expansion is considered to be of great importance. Accelerated or boiling tests are frequently adopted to ascertain the soundness of cement. H. A.



Standard Briquette for Testing Portland Cement.

Cemeteries.—(*See* "Burial Grounds and Cemeteries.")

Cesspool, Self-Emptying Septic.—Forms of self-discharging septic-tank cesspools are being largely used both in urban and rural districts of France. These are improvements introduced respectively by Bezault and Degoux on the old Mouras siphonage cesspool. The Bezault type consists of an air-tight cesspit, divided into two unequal sized chambers by a vertical partition reaching nearly to the ceiling, and perforated towards the base. The soil and rain-water pipes enter the larger section of the tank vertically, but with horizontal outlets to prevent any violent commotion on the introduction of fresh matter. The discharge pipe enters the smaller compartment horizontally, but has the end turned downwards, and at the elbow there is a small ventilation outlet. The sewage is collected in the larger section, where it undergoes liquefaction as the result

of aërobic bacterial activity, air being introduced whenever any material enters the cesspool. The liquefied and drained sewage enters the smaller section, and as soon as the liquid reaches the level of the horizontal discharge pipe siphonage takes place, and any accumulation of gas generated during bacterial action is removed by way of the ventilating orifice with the flow of the effluent. As a rule the purification is not carried very far in such a cesspool, but the effluent is entirely free from flocculent matter, is practically odourless, and in a fit condition for distribution over a contact bed or for broad irrigation. It is impossible for any nuisance from sewer-gas to arise. In the Degoux type there are also two compartments. The first is a water-tight pit, into which the soil pipe discharges vertically. The discharge pipe is horizontal, with end bent downwards, the orifice being protected by a grid or other contrivance to prevent the aspiration of paper or solid matter during discharge by siphonage. This pipe communicates with the top part of the second water-tight tank, which contains a bacterial contact bed, composed of three or more layers of slag broken up into different sizes, resting on a perforated plate, placed a few inches above the base of the tank. Over the filter is an air-inlet pipe. The effluent is discharged through a large valve at the base, and this discharge pipe is provided with a small ventilating shaft, fitted with a vaned cowl, the shaft being carried up above the eaves of a house, or to a sufficient elevation to avoid the causing of any possible nuisance. The discharge of effluent is sufficiently rapid to ensure the necessary supply of air to the contact bed and the dispersal of sewer-gas. The effluent, which is slightly opalescent, is inodourous and claimed to be imputrescible, but sanitary engineers object to its being discharged into any stream before refiltration upon beds or land. The Degoux type has been employed successfully in connection not only with dwelling-houses and factories, but also for the collective treatment of sewage from houses and cottages on estates and from villages.

Cesspools.—Now out of date, yet, frequently made use of, and permissible if properly constructed and placed. Cesspools may be simply sunk in a porous soil, such as chalk or gravel, and lined with loose brickwork. In this case the sewage merely soaks away when liquefied. At a safe distance from dwellings and sources of water supply, there is no objection to this type of cesspool. Other cesspools, which are preferable, are those which are made water-tight and from which an overflow pipe conveys the liquid sewage to some convenient and safe spot for ultimate disposal, which may take the form of land irrigation or treatment on suitable bacteria beds. Many such cesspools which in former years were blindly constructed on right principles are in existence, and have proved satisfactory even though their very position had been forgotten. The essentials in cesspools are a suitable capacity, and placing the inlet and outlet pipes so that sewage entering the cesspool is immersed, and the outflow quite liquid. When, as is frequently the case, the inlet and outlet are placed at the same level, the sewage merely passes from one to the other, thus leading to blockage and nuisance. If both are dipped to about the centre of the contents of the cesspool the heavier solids fall to the bottom while the lighter float on the surface, and only liquid is allowed to escape. In time the solids liquefy by bacterial action and are displaced by fresh solids. A cesspool so constructed closely resembles a "Septic Tank" as to which see "Sewage Disposal."

Chimney Shafts.—Tall chimney shafts, as used for factories and engineering works generally, are usually built of brickwork, but more recently iron and reinforced concrete have also largely come into use. Perforated radiated bricks are employed in the Alphons Custodis system of construction, which also has been largely used in this country of late years. These shafts are of thinner outer walls than the ordinary recognised English mode of construction, and are consequently of less

weight and cheaper to build. The usual practice in this country is shortly as follows:—the brickwork to be not less than 9 in. thick at the top and for 20 ft. below, to be increased $4\frac{1}{2}$ in. in thickness for every additional 20 ft. of height measured downwards. The batter to be $2\frac{1}{2}$ in. in every 10 ft., or an inclination of 1 in 48. In *circular* shafts the outside width or diameter at the base to be $\frac{1}{12}$th of the total height, and in *square* shafts to be not less than $\frac{1}{10}$th of the total height. No cornice or other projection should stand out more than the thickness of the brickwork at the top. The firebrick lining is to be additional to the thicknesses of the ordinary brickwork as prescribed by the above-named rules. This lining should not be bonded in with the brickwork of the outer walls, but be built quite free in order that it may expand and contract without affecting the outer walls. The height to which this lining should be carried up depends upon the heat of the gases and the fluctuations of temperature within the shaft. Usually, in a shaft 150 ft. high the firebrick lining may be advantageously carried up to about 70 ft.: from the bottom of the inlet flue at the base. The top of the shaft may be provided with a cast-iron cap, which is preferable to stone, as the latter is very liable to deteriorate, especially when held together with iron cramps. Cramps, if used, should be of gun-metal, and continuous gun-metal rings are sometimes adopted in circular shafts to bind the stone courses in chimney caps. Special care should be taken to see that the shaft stands upon a thoroughly sound foundation. It is usual to provide an extended base of Portland cement concrete from 3 to 10 ft. thick, according to the necessities of the site, in order to thoroughly distribute the weight of the shaft over a large area. The brickwork foundation is then commenced upon this and gradually tapered up to the proper size or outside diameter of shaft at the finished ground level. A shaft should be built and allowed to settle before connecting up to the main flue to avoid fracture in the brickwork. For the same reason it is advisable shafts should stand alone without connection with any surrounding buildings. The *circular form* of chimney is best and most economical, as the same amount of material covers a greater area, and the effect of wind pressure on the structure is less. Taking the effect of wind pressure upon a *square* shaft as 1, the effect upon a *hexagonal* shaft may be taken at ·75, on an *octagonal* shaft ·7, and upon a *circular* shaft ·5. In practice it is customary to provide shafts of sufficient weight and stability to withstand a wind-pressure of 56 lbs. per square foot of surface exposed, an allowance which was recommended by the Board of Trade Committee on Wind Pressure, and which is well in excess of anything likely to be realised. In calculations for stability of shafts no value is attached to the tensile or adhesive strength of the mortar, the *weight* of the shaft alone must be adequate to resist overturning, so that even during the most severe gale of wind there should be no tension set up in any part of any bed-joint. If a chimney is designed with the thicknesses of brickwork prescribed in the first part of this article its stability will be ensured.

Chloride of Lime, or bleaching powder, $CaCl_2O$, dissolves in water (except the impurities) forming chloride and hypochlorite of calcium, the latter only being available as a disinfectant or oxidiser. The powder should be dry and should contain about $\frac{1}{3}$rd of its weight of "available chlorine" (that belonging to the hypochlorite). It keeps for some time when protected from light and air, which cause it to deliquesce and spoil, while CO_2 liberates hypochlorous acid, giving rise to the odour. It is a bactericide and an oxidiser acting approximately thus: (1) when alone (a slow action), $CaCl_2O = CaCl_2 + O$: (2) with hydrochloric and some other strong acids, immediately, $CaCl_2O + 2HCl = CaCl_2 + H_2O + Cl_2$ (free chlorine): with weak sulphuric and other acids, $2CaCl_2O + H_2SO_4 = CaCl_2 + CaSO_4 + 2HClO$ (Hypochlorous acid). When mixed with whitewash the surface remains damp, owing to the calcium chloride. For

sprinkling use 1 part to 10 or 12 of water; for washing the person 1 to 100. For disinfecting rooms several applications of the 1 % solution are needed.[1] If strong it corrodes metal fittings, and it has sometimes perforated the siphons of water closets, but after the Maidstone typhoid epidemic in 1897 the water pipes were sterilised with a 1 % solution of chloride of lime acting for 48 hours, and no corrosion was observed. Traube in 1894 stated that a quantity of chloride of lime containing one milligramme of available chlorine destroyed in 2 hours all the bacteria in a litre of water (a proportion of 1 per million), but it has since been proved that the amount required is much greater, and such as to make the water hard and undrinkable. Hypochlorite of soda, in the form of "Chloros," or electrolytic, can be used instead, and the writer has found that 1/25,000th to 1/30,000th part of available chlorine in either of the three forms killed *B. typhosus* in 10 minutes. *The strength of commercial hypochlorites in available Cl (normal 33 %) must always be known, and they must be used in proportion to this figure.* Comparative tests with bleaching powder and electrolytic chlorine for the sterilisation of water and sewage effluents show that the latter is cheaper and more efficient, and it is probable that electrolytic plants will be installed in those cases in which a permanent treatment is required. It is even possible to disinfect crude sewage, as, for example, that from a hospital, prior to bacterial treatment, but in this case the cost is proportionally higher. Schumacher, and Dunbar and Korn, conducted some elaborate trials at Hamburg in 1904 with bleaching powder, and established the quantities necessary for the sterilisation of sewage, whilst Chloros has since been used by the London Water Board for Hertford Sewage, and Rideal has similarly used "oxychlorides" (sodium hypochlorite prepared electrically) on the Guildford sewage with satisfactory results. (*See* "ELECTROLYSIS.")

[1] The Board of Agriculture and Fisheries prescribes "a 1% (minimum) solution of chloride of lime containing not less than 30% of available chlorine." Diseases of Animals (Disinfection) Order of 1906.

In the United States the Department of Agriculture in Bulletin, 115, has further investigated the subject, comparing the effect of copper sulphate and chlorine for the disinfection of sewage effluents for the protection of public water supplies. At Ilford bleaching powder has been used for sterilising the effluent from the sewage works after chemical precipitation. About 5 parts per million of available chlorine and a storage of about 2 hours removes nearly all the bacteria, including *B. coli* and any typhoid bacilli present, from an ordinary sewage effluent after bacterial treatment in a modern percolating filter.

S. R.

Chlorine in Water and Sewage.—Chlorides in water (and sewage) are usually recorded as chlorine. High chlorides, unless derived from rocks or from the sea (which contains about 1·9% of Cl), point to contamination by urine, which contains up to 1 % of NaCl, as distinguished from that by fæces, which contain much less, hence the chlorine figure is sometimes a valuable index of the pollution. The urine averages about 1½ litres per head per day, with a mean chlorine of about 0·45 % or 450 parts per 100,000, whereas in most ordinary waters the chlorine is only 1 to 2 parts; in weak domestic sewages it is about 7, in stronger ones it may be 40 or 50, and a common average is 10. For comparing sewages it is often useful to calculate the analyses to a uniform Cl figure, say 10 parts, and the ratio of the Cl to the amounts of the different forms of nitrogen shows the progress of the purification. We may note that (1) rain, unless it has passed over a polluted surface, always diminishes the Cl; (2) a *decrease* in the Cl of a well may indicate surface infiltration; (3) a good well yields a fairly constant figure. The Massachusetts reports give maps of "Isochlors," or lines on which the subsoil water shows equal Cl, but in many countries agriculture renders these illusory. In rivers and estuaries, and on coasts, Cl determinations enable us to trace the course of sewage and of fresh or salt water

(as recently at Dublin, Southend, and other places), and also the infiltration of the sea into water pipes and wells, as at Eastbourne, and the passage of trade effluents. (*See* "Analysis, Chemical"; "Effluents and Standards of Purity"; "Water, Chemical Analysis of.")

Cholera.—Cholera is a specific infectious disease characterised by violent diarrhœa and collapse, causing a heavy mortality, often reaching 50 %, amongst those attacked. In certain parts of India it appears to be continuously prevalent, "endemic," and from time to time it follows the routes of travel to the most distant parts of the world. Sometimes it travels slowly along the route of caravan traffic, at others it travels more rapidly along the course of rivers, and at others it is carried rapidly by ships from port to port. Several times during last century it entered British ports, and in 1832, 1849, 1854, and 1866, wide-spread epidemics occurred; but in 1866 the invasion was far less serious than on previous occasions, and since that date although the infection has been several times imported the secondary cases have been few in number and practically confined to the port of entry. The disease is due to a specific poison, a toxin, produced by a spirillum, the cholera bacillus, during its growth in the large intestine. The organism does not produce spores, and it can readily be grown in nutrient broth and on various solid media. It apparently lives only a short time in water, but may survive a long time in soil under favourable conditions. The evidence, however, on these points is very conflicting. Like the infection of typhoid fever, it is chiefly disseminated by water, milk, and articles of food and drink; but it can also spread from person to person, and it is especially prone to prevail where the sanitary conditions are unsatisfactory. The spirilla are rarely if ever found in the blood or the urine of the patient, but the rice water stools contain them in myriads. From surfaces which have become contaminated flies may convey the infective material to water, milk, &c., and so cause spread of the disease; but doubtless water supplies are most prone to pollution from the washings of soil which has been fæcally contaminated. The last epidemic in Europe, which occurred in Hamburg in 1892, was due to the use of unfiltered water from the river Elbe. Altona, lower down the river, using still more grossly polluted water from the same river after careful filtration, practically escaped until by an accident a little imperfectly filtered water was allowed to enter the mains when a small outbreak quickly occurred. The Hamburg epidemic resulted in the loss of over 8,000 lives within a period of about three months. The mortality amongst those attacked was over 40 %. Within two to five days from the ingestion of the specific poison, the first symptoms of the disease appear, and frequently the early cases of an epidemic are so mild in character as to be regarded as ordinary diarrhœa. The later occurrence of typical and rapidly fatal cases clears up the diagnosis. In districts liable to invasion any outbreak of diarrhœal disease, however mild, should be carefully watched, or the train may be laid for an extensive outburst before the real danger is realised. Wherever pure water supplies have been introduced the ravages of cholera have been held in check. Thus in Lahore the average death-rate from cholera fell from 1·07 per 1,000 population to 0·07 after the provision of a public water supply, whereas the death-rate increased in the district around, where the water supplies remained as before. The annual pilgrimage of Mohammedans to Mecca almost invariably brings cholera in its train, though the great attention now paid to the wells *en route* has considerably reduced the risk of a serious epidemic. Cases of cholera can only enter this country through the ports, and the Local Government Board has issued regulations for the prevention of such importation.[1] Any vessels coming within three miles of the coast of England

[1] P. H. A., 1875, s. 130; P. H. (Port) A., 1896; P. H. A., 1896.

and Wales, and having a case of cholera (or yellow fever or plague) on board must hoist at the mast-head a large yellow and black flag. All vessels from foreign ports are boarded by Customs officers, and if, upon inquiry, they have reason to suspect that a ship is infected, it is ordered to be moored in a place set apart for the purpose until the medical officer of the port has boarded and examined the passengers and crew. A vessel is deemed to be infected in which there is any case of cholera (or yellow fever or plague), or in which there has been a case whilst it was in, or since it has left the port of departure. The medical officer of health can detain the vessel for a period not exceeding two days. Infected persons must be sent to a hospital, suspected persons may be detained two days to enable a diagnosis to be made, whilst those who are well must be permitted to land, provided they give their names and addresses, and intended destinations. These names and addresses are sent to the sanitary authorities for the districts into which the persons are going and the medical officers of health for the respective districts then exercise such supervision as may be deemed desirable until the danger period is past. In some countries vessels are detained in quarantine for a considerable period, but the experience gained at British ports has shown that such prolonged quarantine is totally unnecessary whilst it seriously dislocates trade, and causes heavy pecuniary loss to shipowners and passengers. During the day or two's detention the vessel can be disinfected, and bedding, clothing, &c., be submitted to steam for sterilisation, the bilge water pumped out, and all water receptacles disinfected. The master of the vessel must carry out or permit to be carried out necessary disinfecting and cleansing operations and must burn or otherwise destroy all infected articles if ordered to do so by the sanitary authority or medical officer of health.

J. C. T.

Cisterns (Vessels for the Storage of Water in Buildings).—Although drinking water is best drawn direct from the mains, where mains and a constant supply are available, water must be stored in all cases for eventualities, such as during periods of frozen mains or repairs. Cisterns are constructed of a variety of materials which should be selected with due regard to the characteristics of the water to be stored. Soft water absorbs lead and this material must therefore be avoided if the water has any tendency to act upon it. Zinc lined and galvanised iron cisterns are also undesirable in connection therewith, although less objectionable than lead. Copper-lined cisterns, unless tinned, are even more objectionable, as copper is a metal which is attacked very energetically by water and air, and the salts of copper are very dangerous. Tin, however, has a great affinity for copper, and forms a very durable and protective coating when thoroughly applied. Tinned copper is therefore probably the best metallic lining which can be used for cisterns intended for the storage of water having a tendency to act upon metals.

Cisterns.

Other suitable cisterns which are safe and desirable with all kinds of water are, *enamelled iron cisterns* made in sizes to hold from 40 to 500 gallons of water; *porcelain enamelled stoneware cisterns* made of capacities up to about 60 gallons, and *fireclay salt glazed cisterns* which are obtainable in sizes

sufficiently large to hold from 400 to 500 gallons of water. With all these it is necessary to exercise care in selection, as the enamelling or glazing is frequently rough or fractured. Stoneware or fireclay cisterns are for this reason occasionally apt to prove slightly porous. Slate cisterns are also good, and come next to stoneware cisterns in cleanliness and suitability for the storage of water. They are, however, heavy, costly and liable to leak. Their joints should be made with materials other than red or white lead, as the oxides of lead are soluble in most waters and, of course, poisonous. Black wrought-iron cisterns, painted or washed with lime or cement, are occasionally used. The cement or lime-washing, however, soon wears off, and needs frequent renewal; whilst painting is not always suitable owing to the lead contained in the paint. If iron cisterns are used the safest and most lasting protective coating would be a quick-drying asphalte varnish, of which two or three coats should be applied.

Cisterns, and especially such of them as are connected to taps for supplying drinking water, are amongst the most important of the sanitary fittings of a house, and require at least as much consideration as water closets, or other sanitary appliances. They should be placed in apartments kept exclusively for the purpose and chosen with the utmost care. The room or rooms in which they are placed should be well lighted, warm in winter and cool in summer, and as far removed as possible from those portions of the house in which sanitary fittings or bedrooms are situated. All care must be taken to prevent the pollution of the water by dust, vermin or foul air, for which purpose each cistern should be provided with a close fitting removable cover. When vermin and dirt are the only impurities to be guarded against, a wooden lid constructed of tongued and grooved boards or of matchboarding, will be sufficient; but if there be the slightest possibility of contamination by foul air or gases—such as from bedrooms or from ventilation pipes on drains or from the house—then the lid should be absolutely air-tight, both in itself and in its fixing to the cistern. The ideal cistern, as was pointed out by the Commission on the East London water-supply, would be a mere local enlargement of the service pipe, perfectly closed except for a minute valve, and preferably of a conical shape, so as to be self-cleansing. Such cisterns are upon the market (*see* Figure, p. 75).

In order to efficiently guard drinking water against aërial contamination, it is also essential that all ordinary cisterns containing such water should have their overflow pipes arranged to discharge into the open air at some point at which the overflow pipe is not exposed to emanation from drains, sanitary fittings, or other sources of polluted air. Nor must any water closets, urinals, or housemaids' slop-sinks be flushed directly from the service pipes or from any cistern containing potable water. The latter would be liable to be polluted by means of foul air conveyed to them from the sanitary fittings through the flushing pipes; whilst, in the case of service pipes, there is a strong tendency for foul air to be drawn into these when emptied through any cause.

It is for these reasons that most sanitary authorities require the fittings mentioned to be flushed from separate cisterns. The requirements of water companies and corporations, by which it is necessary to provide water-waste preventing cisterns, are also beneficial, although, perhaps, framed mainly for the prevention of waste. For details of these see "WASTE PREVENTERS." G. J. G. J.

Cleaning Eye.—A round aperture on a pipe, usually in the nature of a branch socket,

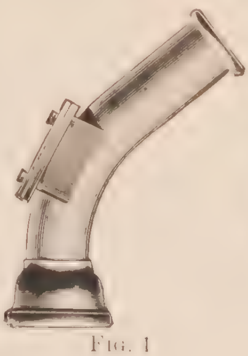


FIG. 1

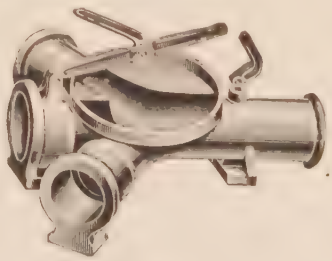


FIG. 2.

provided for cleaning purposes and fitted with a movable cap or cover capable of being closed air-tightly. Cleaning eyes are usually provided on waste pipes; also on disconnecting traps for giving access to that portion of the drain which lies between the trap and the sewer. (*See also* "ACCESS PIPES.")

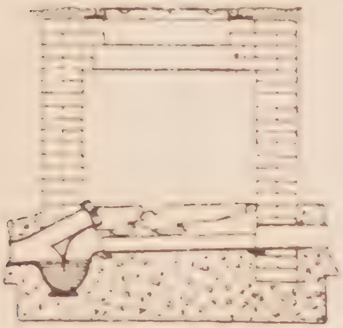


Fig. 5.

Clinker from Destructors.—(*See* "DESTRUCTORS.")

Coagulents.—(*See* "FILTRATION.")

Coarse Beds, Bacterial.—(*See* "SEWAGE DISPOSAL.")

Cocks.—A valve or tap for controlling the flow of water through or from a pipe. Strictly, a cock is a fitting having a conical plug with its axis at right angles to the flow through the pipe and provided with a slot or opening which, when in the direction of the flow, permits water to pass through. When the slot is at right angles to the flow the water is turned off. Cocks are not desirable fittings as they shut off the water too suddenly and give rise to the percussion known as water hammer when the water is under pressure. (*See also* "VALVES.")

Colloidal Matters in Sewage.—The substances in sewage which are not removed by ordinary filtration or sedimentation are of two kinds, (1) *colloidal*, amorphous, of considerable viscosity, and almost incapable of diffusion, like albumen or gum; and (2) *crystalloid*, capable of crystallisation and diffusion, and much less viscous, like, typically, common salt. The former are in a more or less unstable condition, and Graham, whose work first made the difference distinct, introduced the terms still in use of "sol" for their apparent solution, and "gel" for the gelatinous result of their coagulation or change; the words are frequently extended into "hydrosol" and "hydrogel" to include in them the presence of water. Although most of the colloids are organic, probably all solids in conjunction with liquids are capable of assuming, at least temporarily, the colloidal state: that is (1) they may be in such a fine state of division as not to be separable by filtration; (2) they leave the liquid clear or only slightly turbid, so that their presence may be solely detectible by the ultra-microscope—that is, by a concentrated beam of reflected light; and (3) they can be flocculated and precipitated by addition of small quantities of chemical substances, also sometimes by heat, and sometimes by adhesion to surfaces. In forming a "gel" a colloid always combines with and entangles a considerable amount of other substances present; this property, especially when it affects matters in solution is called "adsorption," and is a conspicuous feature of methods of precipitation of sewage by the inorganic "gels" of ferric oxide and alumina, obtained by adding an acid salt like "alumino-ferric," and then lime. In this case, since a number of organic substances prevent the precipitation of metallic oxides, it is necessary to ascertain the quantities by trial, in order that the effluent should not contain more than traces of the precipitant. It is possible by suitable chemicals to greatly decrease the colloids in sewage, but with considerable expense and an excessive sludge. A large portion of these colloids are deposited in simple sedimentation, if time can be allowed, but this deposition is greatly accelerated by their property of adhesion to surfaces. In filtration a slimy layer forms on the material, and acts *mechanically*, by entangling suspended matter, and *biologically* by the large number of organisms growing in it ("Zooglœa"), which occasion chemical changes in the liquid passing through, and if properly managed effect a great purification. At the same time the working of filters is largely influenced by the viscous properties of the colloids, acting by (1) causing

the liquid itself to flow more slowly; (2) diminishing the capacity on account of the gelatinous deposit on the medium; (3) retarding the previous deposition of suspended matter. Hence the advantage of a preliminary passage over surfaces, as in the Scott-Moncrieff cultivation tank or in Travis's "hydrolytic" arrangement. Besides the mucous matters in domestic sewage, a number of other viscous substances are often added by manufactures and may necessitate some form of chemical precipitation. Blitz's work on the different polarity of the colloids, the gummy and the albuminoid class being electrically negative, and the metallic hydroxides positive, helps to explain why definite quantities of precipitants are necessary, and why electric currents, passage over surfaces, or addition of electrolytes can cause coagulation. Anaërobic action in septic tanks, and defective aëration in filters increase the amount of colloid matter in the state of "hydrosol," which also usually becomes higher with increased temperature, while high nitrification generally coincides with low colloids in the final effluent. The amount of these substances in sewage has been determined by dialysing the filtered liquid through parchment, or through porous porcelain (Thorp): upwards of 30 to 50 °/。 of the organic matter will not diffuse and is therefore colloid. A similar figure is obtained more rapidly by precipitating by basic ferric acetate. Fowler for his "Clarification Test" adds to 200 c.c. of the sample 2 c.c. of a 5 °/。 solution of sodium acetate and 2 c.c. of a 10 °/。 ferric ammonium alum solution, boils for two minutes, cools, filters, and analyses the clear liquid.

O'Shaughnessy found (Birmingham sewage) that the matter which separates on allowing a clear septic tank to stand has only a faint odour, is extremely stable, and even when incubated with water under the most favourable circumstances decomposes with extreme slowness. These properties sharply distinguish this matter from the original sewage sludge. He mentions incidentally that the colloid matter usually present in land effluents is very small in quantity and contains much mineral matter consisting mainly of ferric hydrate and silica. Other investigators [1] have shown that the products of a proper septic fermentation and sedimentation of sewage resemble the humus of peat, are practically inoffensive, and contain about 7 parts of carbon to 1 of nitrogen, associated with iron and other inorganic matter. S. R.

Columbaria. — (*See* "CREMATORIA AND COLUMBARIA.")

Combined Drainage System.—The combined drainage system is that in which the surface-water from a district is carried away by the same sewers which convey the sewage. Most English cities and towns are drained on this system, the original practice having been to turn sewage, rain-water, and even subsoil-water into the same set of sewers. The points urged in favour of the combined system are that it is simpler and cheaper to have one set of sewers than two, and that the rain-water admitted to the sewers is valuable for flushing them. Its disadvantages are the excessively large sewers which it generally necessitates, and the consequent sluggishness of the dry-weather flow in them; and the difficulty of dealing with large volumes of storm water at the outfall. Whether the sewage is to be purified on land or in artificial works, it is important to keep the flow within moderate limits; and where it has to be pumped, the admission of surface-water will generally entail a very large addition to the cost of this operation. The "combined system" is therefore very generally discarded in favour of the "separate system" (which see), though for various practical reasons it is seldom possible to carry out the latter in its entirety. The washings from the roads, especially after a long spell of dry weather, are often fouler than the sewage. London is a good example of a city sewered on the combined system. A. J. M.

Commin Separator, (Sewage Disposal).—This consists essentially of a shallow

[1] Adeney, "Trans. Roy. Dublin Soc.," Sept., 1895, and Aug., 1897; Rideal, "Brit. Assoc. Reports," 1901.

tank with grit chamber of sufficient capacity to steady the flow of sewage so as to permit of the heavier suspended solids sinking and the lighter matters rising. The object of the "separator" being to thus remove the coarser suspended solids in the sewage in order to render the liquid portion capable of further treatment upon bacteria beds or by other means. With the object of assisting in the settlement of the solids, the flow from the tank is divided over the edges of a large number of small channels at the surface all set level with each other, thus forming a long length of weir, and the velocity of approach of the sewage sought to be secured is such as to ensure the precipitation of the finely divided solids. Like ordinary settling tanks, these "separators" should be provided in duplicate for continuous work so that a section may be cleared daily. A "separator" 33 ft. × 18 ft. : is considered capable of treating 30,000 gallons per hour. A separator plant is in use at Dorchester where the tank is divided into four compartments, the sludge from one of which is emptied daily by first removing the whole of the supernatant water. The population of Dorchester is about 10,000 and the dry weather flow, which is diluted by leakage into the sewers, 45 gallons per head. The grit chambers in connection with the separators are reported to remove some 4 or 5 tons of stiff sludge per day and the separator another ¾ of a ton. After leaving the "separator" the sewage passes into what was formerly a septic tank, now used as a sedimentation tank, in this way a further 2 to 3 tons of sludge is removed daily, due apparently to the much larger capacity of the septic tank. Since the Dorchester plant was constructed improvements have been introduced with the object of overcoming the difficulties in working experienced in that installation. (*See also* "KESSEL-SEPARATOR.")

Compensation Water.—When the watershed of the upper reaches of a stream is appropriated by a public water authority, a definite statutory obligation is usually imposed upon such authority to deliver into the watercourse flowing from the watershed proposed to be utilised for purposes of a public supply, a stipulated quantity of water daily for the use of millowners, agriculturists, and others interested in the water-rights of the stream. The water so supplied is known as "compensation water." (*See* "WATER SUPPLY.")

Compressed Air.—Compressed air is extensively used for transmitting power to distances, raising water from boreholes, lifting sewage by displacement, &c., &c. According to the well-known law of gases, the pressure of a quantity of dry air is inversely proportional to its volume, provided its temperature remains the same; thus if a cylinder full of "free" air, *i.e.*, air at atmospheric pressure (14·7 lbs. per square inch), were compressed by a piston, without increase of temperature (isothermally), to half its former volume, the resulting pressure would be 29·4 lbs. per square inch. When air is compressed, however, its temperature is raised, and, unless the heat due to the work of compression could be abstracted during the process, such compression would not be performed "isothermally" and the above conditions would fail to be realised. If the temperature acquired by compression is retained, the rise of pressure will be more rapid than the inverse ratio of the volume, and will assume the proportion known as "adiabatic" (no heat passing). As this heat will be dissipated after the air leaves the compressing cylinder, a proportionate shrinkage in volume and loss of pressure will take place, with the result that a corresponding amount of work will have been wasted. From this it is evident that the more closely compression follows isothermic conditions, the more efficient will be the process. To remove the heat, compressor cylinders and, in some cases, the pistons, are water jacketted; but as air is a slow conductor of heat this is only a partial remedy. A further attempt towards economy consisted in spraying water into the cylinder, but the latter and similar

plans were open to practical objections. The best solution of the difficulty was to divide the compression into two or more stages and to cool the air between each stage in a kind of surface condenser. As the difficulties of cooling during compression increase with the pressure, it is usually advisable to employ "stage" compression for pressures over about 70 lbs. per square inch. The air, after being compressed, may be stored in receivers if the work is of a nature to require it, and may be conducted considerable distances with slight loss. In employing compressed air as a motive power behind a piston (as steam in an engine) the air is, when practicable, allowed to expand until at the end of the piston stroke it is nearly down to atmospheric pressure. As air is heated by compression it will, conversely, be cooled by expansion; this leads to a further loss in the motor, and may also cause trouble at the exhaust ports by freezing the moisture contained in the air. The air is, therefore, re-heated before it enters the motor, usually by passing it through a jacket or coil heated by some inexpensive fuel. The gain in efficiency far outweighs the cost of re-heating. (*See* "Air Compressor.") E. L. B.

Concrete.—Formerly lime concrete was largely used for foundation work on land, but it is now unknown, if we except the occasional use of lias lime for the purpose. This is due to the abundance and low price of Portland cement which sets well under all conditions and produces a far better result. Concrete is generally described as consisting of a matrix and aggregate, the matrix being Portland cement and sand in the form of mortar, and the aggregate the large material forming the bulk of the mass, such as stone, gravel, brick, &c. The proportion of cement used is the main element of cost and it is therefore kept down to the lowest limit consistent with the strength required in the mass. Where the mass is subject mainly or wholly to compression a weak mixture only is necessary, say 1 part of cement to 8 of the aggregate; this would apply to concrete in heavy retaining walls and under the base of ordinary walls. For basement floors where it is subject to irregular loading and unequal expansion of the soil below, 1 to 6 is more suitable, but for modern reinforced concrete work 1 to 4 is found necessary. The aggregate may be varied according to what is available, broken stone, brick, furnace slag, flints, flint gravel, shore ballast, pumice-stone, or coke breeze. The limitations, however, should be made that coke breeze should only be used for dry situations such as upper floors, and that only brick, furnace slag, pumice-stone, or coke breeze should be used for fireproof or fire-resisting floors. Red ballast from burnt clay is of no value for concrete. The material used should be graded, that is, of various sizes from $\frac{1}{4}$ in. up to 1 in. as a maximum for fireproof floors and reinforced work generally, and up to 2 in. as a maximum for other work. The character of the aggregate determines the proportion of sand, which should be sufficient to fill the interstices, and the cement should then be sufficient to coat every particle of sand and aggregate and fill up the smaller interstices. Generally speaking, this will give mixtures of 1 : 2 : 4, that is, 1 cement, 2 sand, 4 aggregate, for floors and reinforced work, and 1 : $2\frac{1}{2}$ or 3 : 6, to 1 : 3 : 8, for other purposes.

Mixing.—For hand-mixing a wooden platform should be laid down to avoid any earthy mixture, say, a dozen scaffold boards laid side by side on a level piece of ground. An open frame or box with no top or bottom, 3 ft. square and 18 in. deep (inside dimensions), should be used to measure the large aggregate; this will contain $\frac{1}{2}$ cu. yd., equal to $13\frac{1}{2}$ cu. ft., when filled level. Then a similar frame, 2 ft. by 2 ft. by $1\frac{1}{2}$ ft. deep, if placed on top of the other and filled with sand would give the right proportion for ordinary foundations. Then $2\frac{1}{4}$ cu. ft. of cement will be required, or $1\frac{3}{4}$ bushels, and this is usually the total amount contained in a two-bushel sack of cement, so that the sack

of cement is emptied on top of the sand without needing any box to measure it. The boxes are then removed, and two men standing on opposite sides shovel the material over so as to mix it. A second pair of men continue the process, until the colour is uniform; then they turn it back again while it is being watered through a rose so as to moisten it completely throughout the mass without washing any cement away. It is then filled into barrows and wheeled away at once to the trench; if the trench is shallow it may simply be tipped in, but if deep the concrete should slide down a trough. Not more than 1 ft. thickness should be laid at one time, and it should be lightly rammed to consolidate it. It was formerly the custom to specify that it should be thrown from a height of not less than 10 ft., but it was found that this caused all the large stuff to go to the bottom, and where any of that previously laid had begun to set it caused disintegration. Each batch of concrete should be used within one hour of mixing and should not be disturbed afterwards. In important works the voids in the aggregate should be carefully measured in order to ensure that the mixture shall be in the best proportions to secure final solidity. This is done by taking a zinc-lined box of given capacity with an outlet tap in the bottom, filling it up with an average sample of the aggregate, then filling with water and making up the water to the level of the top as it soaks into the material, then running off and measuring the unabsorbed water, which will represent the voids in the mass. For machine-mixing there are two classes of apparatus, the continuous mixers and the batch mixers; the latter are the better type. Machine-mixing is only profitable on large jobs and then the cost is much reduced. Some authorities recommend that the cement and sand should be made into mortar before mixing with the aggregate, but the preliminary dry mixing of all the materials is more usual.

Laying Promenades. — After paring the surface to a level and filling and ramming any soft places with ashes or dry brick rubbish, a layer of 3 in. of broken brick should be put down and rolled to a level surface, well watered, and then the concrete laid in portions 10 ft. or 12 ft. square, each portion divided from the adjoining one by a wood strip, or, better still, a strip of sheet-iron, smeared with soft soap, which can be more easily withdrawn. These, which are known as expansion boards, are removed as soon as the concrete has set, and the joint is then grouted up if too wide to leave. This method is generally effective in preventing the unsightly cracks which so disfigure some pavements. The chief point is to have the cement thoroughly air-slaked before use and to see that it is neither over limed nor over clayed. Neat cement floating should be applied to the surface while the concrete is still moist, to secure proper adhesion.

Concrete in Heavy Work.—In concrete dams and heavy walls, engineers require the cement to be as slow setting as it can be made without detracting from its strength, so that initial stresses may, as far as possible, be avoided by the mass being able to adjust itself before it becomes too rigid. H. A.

Condensers.—(*See* "Steam Engines" and "Indicators.")

Condensing. — Condensers are of two principal classes, viz., *jet condensers* and *surface condensers.* The *jet condenser* consists of an iron chamber of almost any convenient form in which the exhaust steam from the engine cylinders and the cold water spray which is injected to meet and condense the incoming steam may be freely mixed. The bottom of the chamber, or "hot-well," in which the condensed water accumulates, is in communication with an air pump (which may be worked from the engine piston rod), the object of which is to draw off the water and any air or vapour contained in the chamber. From the hot-well the water is returned by means of a suitable feed-pump to the boiler, thus securing a considerable thermal advantage over the use of cold feed. The steam inlet pipe into the condenser consists

of a plain pipe entering at the top of the condenser, and the cold spray is injected through a perforated pipe or rose carried well into the centre of the condenser so that the water may be well distributed and the steam on entry immediately condensed. The jet condenser is made of about one-third the capacity of the cylinders exhausting into it. In the *surface condenser* the cooling water and the steam do not come into contact, but are separated from it by the large surface of a number of small metal tubes contained in an outer casing of cast iron. The cooling water circulates through the tubes, the exhaust steam is condensed around them, and the resulting hot water is removed by the air-pump to the hot-well, from which a feed-pump delivers it back to the boiler. Where surface condensers are used in connection with waterworks pumping plant, it is unnecessary to have a separate circulating pump to force the cooling water through the condenser, as the water pumped by the main engines may be made to circulate through the condenser. Owing to the quantity thus passing through, the water is not heated to any appreciable extent.

The advantages of condensing are two-fold. In the first instance the engine has the advantage of exhausting into a partial vacuum of say 27 or 28 in. instead of against the atmospheric pressure, and the fuel consumption is also economised by the return of hot feed to the boiler instead of cold. For surface condensers allow a *tube surface* of $\frac{1}{9}$ sq. ft. to $\frac{1}{10}$ sq. ft. per pound of steam condensed per hour for circulating water not exceeding 65° F. at inlet, or, another rule is a tube surface of 1 sq. ft. to 1·8 sq. ft. per I.H.P. with tubes $\frac{5}{8}$ in. or $\frac{3}{8}$ in. diameter and $\frac{1}{20}$ in. thick. (*See also articles* "INDICATOR" and "STEAM ENGINE.")

Conder's Sulphate of Iron Process of Sewage Purification.—This system was advocated by the late F. R. Conder, M.I.C.E., who proposed that a solution of iron should b3 added to the sewage of each house by the use of an instrument called a "*ferrometer.*" A small stream of water flows through the ferrometer, dissolves the sulphate of iron, and carries it into the sewers. A slice of lemon is placed weekly in the instrument to add a vegetable acid. It was also proposed to place trays of sulphate of iron in the street man-holes, the chemical being dissolved by a small stream of water. The system has been tried upon a small scale at Chichester Barracks and in Bermuda with satisfactory results, but is not suitable for dealing with the sewage of a town. The cost of installation and royalty is put at about £36 per 100 people, and of chemicals at 6*d.* per head per annum. The cost of labour, attendance, and the removal of the resulting deposits from sewers would appear to be a bar to the extended use of such a system.

Condy's Fluid.—"Condy's Green Fluid" is a strongly alkaline solution of sodium manganate, Na_2MnO_4, with much sodium chloride and some permanganate. The "Red Fluid" is a purer sodium permanganate. Crystallised potassium permanganate, $K_2Mn_2O_8$, which is pure and fairly cheap, is preferable to either, but as a disinfectant it is still very costly, and, moreover, unsafe, on account of its almost immediate destruction by organic matter. The writer had unfavourable results with street watering.[1] (*See* "DISINFECTANTS.")

Connections—House Drains to Sewers.—That portion of the drainage of a building which lies between the disconnecting trap of the drain at its outlet and the public sewer. This drain is frequently laid by the local authority, as it involves the tapping and connecting up to the sewer and the taking up of part of the highway. The cost of the work, however, falls upon the owner of the house.

Conservancy System.—The conservancy system of excrement disposal is that in which the nightsoil is retained in pans or pits, instead

[1] "Sanitary Record," July 27th, 1900.

of being carried away in pipes, as in the "Water-carriage System." In some cases the dejecta are received in large built pits, into which the household ashes are sometimes thrown, and which are emptied periodically. Another and better plan is to use pails or pans, which are removed and cleansed at short intervals. In earth-closets the dejecta, as deposited, are covered with a little dry earth. The conservancy system is largely employed in country districts, the nightsoil being used as a manure. It also survives in a number of large towns in the Midlands and North of England, and in the Colonies, but it is unfavourably regarded by the health authorities, and its supersession by the water-carriage system is merely a question of time. The main point in its favour is that it conserves and returns to the soil the manurial constituents of the excreta. On the other hand, the retention of fæcal matter near houses is offensive, and even dangerous, more especially in view of the action of flies in conveying infective material from the closets to the larder.

A. J. M.

Contact Beds, Bacterial.—(*See* "Sewage Disposal.")

Conveniences, Underground. — **Acts of Parliament—Points to be Noted—Site—Excavation — Walls — Drainage — Roof — Staircase — Ventilation — Sanitary Fittings — Plumbing, &c. — Attendant's Cabin — Framing — Locks — Lighting—Cost.**

Acts of Parliament.—Power to borrow money for the purpose of providing underground conveniences and lavatories within the metropolis is contained in sect. 105 (2) (*a*) of the Public Health (London) Act, 1891, and, in the provinces, the Public Health Act, 1875, sect. 39, gives an urban authority power, if they think fit, to provide and maintain conveniences, while the Public Health Acts Amendment Act, 1890, sect. 20, gives the urban authority power, if they think fit, to make regulations for the management thereof, and to make bye-laws as to the decent conduct of persons using same. Also the urban authority may let the convenience for a term not exceeding three years, or may charge such fees for the use of the water closets as they may think proper.

Points to be Noted.—When choosing a site for an underground convenience (and only such are referred to in this article) the following points should be considered:—1. Central position with regard to the necessity for such a structure. 2. Position with regard to lines of traffic. 3. Available depth with regard to sewers and risk of flooding when sewers are surcharged. 4. Stability of foundation. 5. Absence of gas, water, and other mains or facility of diverting them if encountered.

Site.—Persons requiring the services of such a structure usually seek them in large open spaces, and since, owing to their construction, they form a useful landing-place or refuge among the traffic, it is in keeping that the position should be chosen with great care, and that they should be so placed as to be *en route* from the corner of one street to the corner of another, and yet allow at least two lines of traffic to pass along each of their sides, and their proximity to tramway lines should not be less than 9 ft. 6 in. to the nearest rail.

Excavation.—In forming the excavation great care should be taken in view of encountering the mains belonging to the various gas, water, and other companies, as damage to same might unduly prolong the work, and cause an unnecessary interference with the street traffic. The question of the existence of such mains should be fully gone into before the scheme has finally been decided on, as it sometimes happens that a diversion may either be impossible or very costly, and the subsequent alteration of the convenience render it the less commodious and inconvenient in administration. When arranging details prior to commencing the work, it will be found convenient, in a work on so restricted a space, to have all material delivered at one end and the *débris* carted away at the other. Also rather than extend

the area of the enclosure to provide for a foreman's office and so impede the traffic, it may be found possible to erect it on a low scaffold overhead. The excavation should be the neat width of the outside walls, and no footings should of course project beyond the outside face of the outer walls. The depth of concrete under the walls should be 12 in. to 18 in., according to the local conditions of the subsoil, and project beyond the internal face of the wall for at least 12 in.

Walls.—The walls are generally constructed of an outer thickness of 12 in. of Portland cement concrete, and faced on the inside with 14 in. or 18 in. of brickwork, between which and the concrete backing is a vertical damp-proof course of asphalte, with also one laid

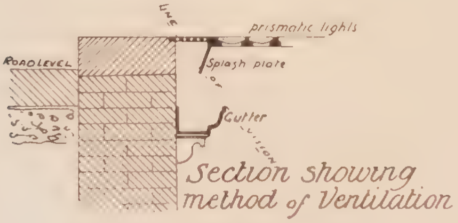


Fig. 1.

horizontally. Occasionally the whole of the wall is composed of concrete, which should be formed in two thicknesses, with the vertical damp-proof course inserted as previously mentioned. The inside face of the walls where constructed of brickwork is often of glazed bricks, but as these have to be frequently cut for fixing pipes, plugs and holdfasts, the subsequent making good often presents an untidy finish. It is preferable to cover the rough brickwork or concrete with ⅜ in. tiles of brick pattern, thus obtaining a finer joint than with bricks, and a better finish may be obtained to soffits and scribing than by the use of glazed bricks. Some conveniences have been faced with opal glass tiles as supplied under various trade names and of different makes. The use has been attended with more or less success. It is thought by some engineers that the vibration of the street traffic has a tendency to crack the tiles, although the fineness of the joints, choice of colour, and ease with which they can be cut to fit around awkward corners is an argument in their favour. The floor should be constructed of concrete, and covered with tiles.

Drainage.—The drainage of a convenience is a matter of supreme importance. No such structure should be built which cannot allow of an adequate fall in the drain from the interceptor to the sewer, and also be at such a relative level above the sewer that no back flow may occur from flooding, due to rainfall, rise of tide, &c. There are two possibilities likely to occur with every convenience, namely, the risk of flooding, due to (1) the flow in the sewer, and (2) stoppage in the interceptor, and to deal with this until the outlet of the drain may be free there must be constructed a storage chamber under the floor of the convenience of a size calculated to be sufficient to retain the sewage until the difficulty has been removed. The storage capacity of the chambers in the convenience illustrating this article is represented by two connected tanks, each 3 ft. deep, and holding together 1,800 gallons, and serving to retain the water from 9 w.c.'s, 11 urinals, 3 urinettes, and 4 lavatory basins. Of course when the outward flow from the drain is restricted, the attendants minimise the use of the wash-basins and the automatic flush to the urinals as much as possible. The chambers, which are practically large manholes, may be faced with glazed bricks, and are formed on the invert, with white glazed half round pipes, and cement benchings. One chamber should be constructed in each of the male and female compartments, and each w.c. connected thereto direct. The urinals and lavatories may be grouped in sets, and each set also connected direct. A sparge pipe should be fixed around each chamber at the top, and connected with the water supply, and be under the control of the attendant—this is to wash down the sides of the chamber after the retained waste water flows off. As this pipe will be at the furthermost extremity of probably a shallow manhole, it will be difficult of

access; therefore it should be of copper, as this is not liable to rust either inside or out. Air-tight manhole covers should be provided to each chamber, and it is usual to make provision for tiles to be let in the top to match the general tiling of the floor. The waste from the w.c.'s, lavatories, &c., should discharge into a manhole after leaving the storage chamber and before passing through the interceptor. A penstock should be placed on this pipe so as to prevent the waste from entering the manhole, when required, thus impounding it in the storage chamber. The reason for this being that in case of the his chambers have become so filled that they overflow on to the floor of the convenience. To cope with this the author has devised a ball and lever arrangement fixed in one of the chambers, and so made that when the ball floats owing to rise of water it will raise a rod connected with an electric bell which will act as a warning to the attendant.

Roof.—The roof is the one portion of the structure which will probably give a considerable amount of trouble and annoyance to those concerned, either from leakage due to outside moisture or from sweating due to condensation of internal moisture. The convenience should

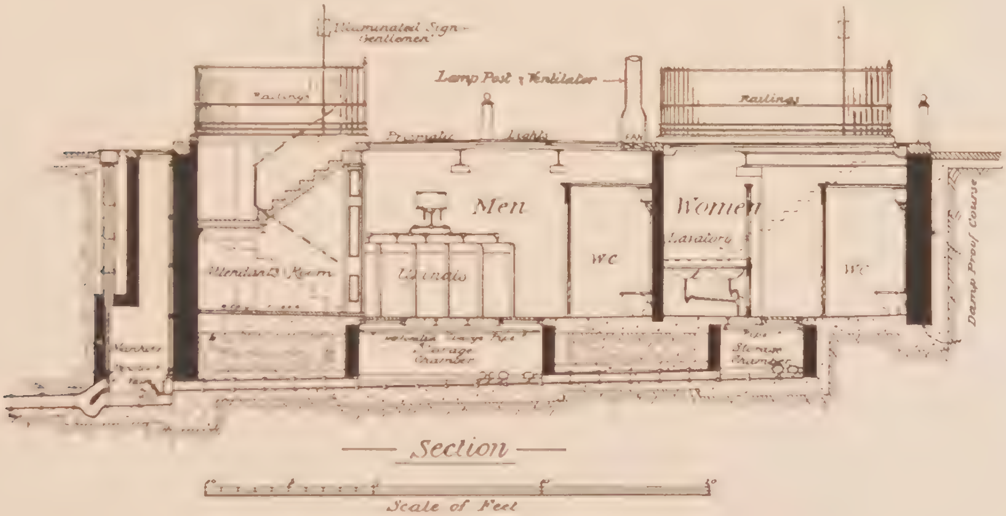


Fig. 2.

interceptor being stopped, the waste from the w.c.'s, lavatories, &c., may be retained, and the manhole pumped dry so as to allow the obstruction to be removed from the interceptor. A penstock should also be fixed over the interceptor, so that it may be closed down at a time of flood in the sewer, to prevent the sewage finding its way either into the manhole or the convenience. This is extremely useful at night, if the penstock is closed down before the attendant leaves. The manhole containing these two penstocks should be accessible only from the surface of the ground outside. There are occasions when the sewer may be in flood, or the interceptor be stopped, and the attendant be unaware of the fact until he discovers that

be so designed that the roof may be about 10 ft. 6 in. above the floor. The construction of the roof should be of wrought iron or steel joists carrying prismatic lights, and care should be taken that a sufficient gradient is given to the frames containing these lights to throw the water off as quickly as possible. Large areas of prismatic lights are subject to considerable expansion and contraction during the varying temperatures, and as this is the main cause of leakages, arrangement should be made whereby the lights should be divided into sections and so reduce the ultimate contraction and expansion. The joints between the frames should be made with a pliable cement. Should any part of the convenience

be under the carriageway, the design of the roof will require more attention than otherwise, as provision must be made for heavy motor traffic. The construction in this case might consist of steel girders supporting brick arches, with the crown and haunches filled in with concrete, or reinforced concrete might be used instead and the top of the concrete then be paved with wood blocks or asphalte to form the surface of the road. That part of the roof which contains the prismatic lights and is not available for vehicular traffic should be formed a step higher than the road and surrounded with a wide granite kerb, heavy cast-iron guard-posts, and granite spur stones. Various devices have been tried to deal with the condensation of the moist internal air in relation to its corrosive action on the iron-work. The most successful method is to cover the paint and varnish with fine cork dust while the varnish is still wet.

Staircase.—The rules covering the entrances and exits are such as would suggest themselves in any ordinary building. If two staircases cannot be provided, one for the entrance and the other for the exit, the width of the single stair should be sufficient to allow of two persons passing one another. The top step should be so placed as not to come within a distance of about 3 ft. from the carriageway, so as to prevent a person stepping directly in front of the traffic. The staircase should be formed with easy steps and as few winders as possible, but owing to their narrowness and the great amount of traffic, the treads will be subject to considerable wear, unless some of the various patent treads are used, such as are to be found on the market, but whichever form is adopted they should be so fixed as to be capable of renewal expeditiously and without much damage to the surrounding work. A considerable amount of water will flow down the steps both during rain and when washing down. A channel with a grating over it should therefore be fixed at the bottom, having a pipe connected to the manhole so as to carry away any water that may flow down. The staircases are usually protected with ornamental pailings about 5 ft. high, having a padlocked gate at the entrance. To screen the interior of the convenience it is customary to cover the pailings with wired rough plate glass. Owing to conveniences being frequently burgled at night-time, either for the sake of the brass fittings or the money in the automatic locks, it has been found necessary to construct a collapsible gate at the foot of the staircase and also a horizontal grating, level with the top rail of the palings, having a portion so made as to slide backward and forwards, and when drawn towards the gate and locked it forms an effectual cage, entirely covering in the staircase and preventing people climbing over for unlawful purposes.

Ventilation.—Various methods are adopted to ventilate the inside of the convenience. A ventilating column may be fixed on the wall dividing the male from the female sections, having a revolving fan, driven by electricity or water. In the latter case the waste water may be used for flushing the urinals. The column is generally utilised as a lamp-post for lighting purposes, and may be of an ornamental character. Another method of ventilating may be by a continuous iron grating about 6 in. or 9 in. wide fixed level with the top of the prismatic lights, thus forming an opening all round the structure. Rain and dirt which will go through are caught in a heavy pattern cast-iron gutter, and the water is delivered into the drains through a square section rainwater pipe, chased into the wall. Splashing of water and a direct line of vision into the convenience from the outside is prevented by a 6 in. to 9 in. width of zinc or sheet iron placed at a suitable angle so as to drip into the gutter. Frequently both methods of ventilation are used in conjunction with one another.

Sanitary Fittings.—The sanitary fittings for a convenience are made in many designs and of various shapes, and it must be left to the fancy of the engineer to choose for himself. It is preferable to adopt a design that can be easily cleaned in all its parts and renewed if

broken. The urinals may be formed with an open channel attached, the latter being covered with a galvanised or brass grating. The division between each stall may be St. Anne's or other marble or even polished and oiled slate, or it may be of the same material and colour as the urinal itself, and the urinals should be 24 in. from centre to centre. The w.c. pans should be quite self-cleansing, with one flush, the "wash down" type being the best. The w.c. compartments generally the opposite direction to a w.c. Some of the patterns also have a perforated grating on the trapped outlet instead of the free-way of a w.c. trap. As a rule the purpose and method of using a urinette is not understood by those who enter a women's convenience, and they are frequently put to the purpose of a w.c., hence their existence becomes either useless or a nuisance. In many of the conveniences where urinettes have been fixed, the usual wooden door has been dispensed with, and

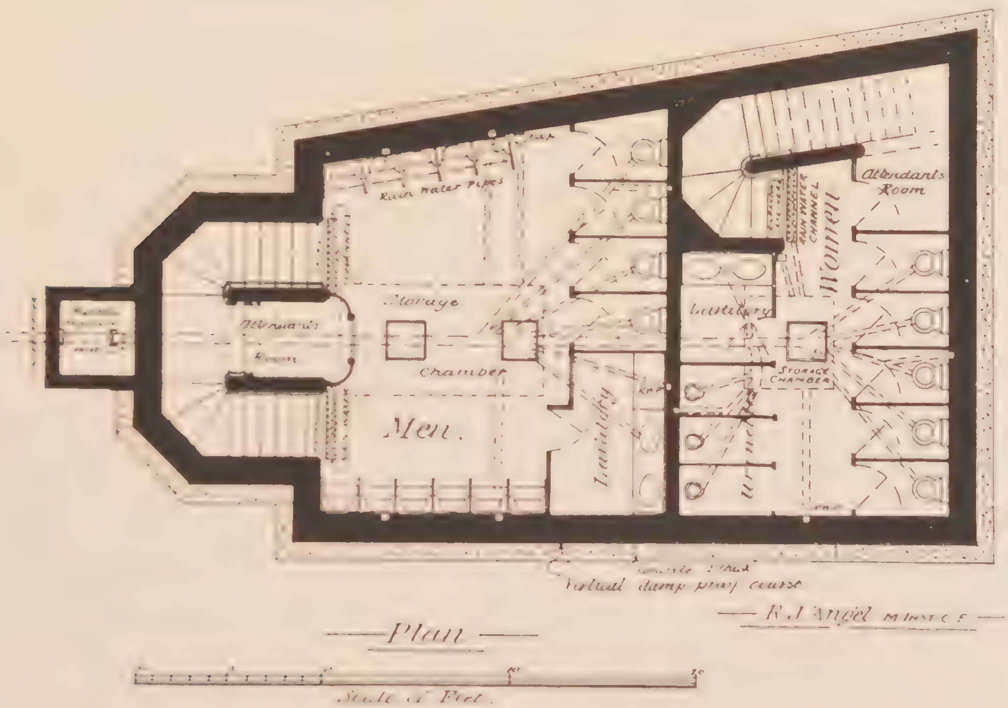


Fig. 3.

measure about 6 ft. by 3 ft., and are divided by marble divisions $1\frac{1}{4}$ in. or $1\frac{1}{2}$ in. thick and 7 ft. to 7 ft. 6 in. high. An addition to the women's section has been made recently in the form of a "Urinette." This has been an attempt to do away with the objection that a man may use a urinal free, while a woman has to pay for a similar purpose. These urinettes are in form similar to a w.c. pedestal; some patterns are narrower than the w.c. pan, the intention being that the users may stand over it with their face towards the wall or in waterproof sheeting hung as a curtain in place thereof.

Plumbing, &c.—The plumbing and fittings should be of the best and simplest of their kind. The water supply to each section should be separately under control to enable any particular part to be shut off for repairs. A tap should be provided inside each of the conveniences with nozzle for a hose pipe, likewise a hydrant should be fixed outside and suited to the same hose pipe for washing down the roof and steps. Hot water should be provided

in each of the lavatories by a geyser. Also the attendant should have a stove for warming and cooking.

Attendant's Cabin.—The attendant's cabin should be made as large and airy as possible, and so placed as to command a view of the whole of the convenience and the staircases, and be provided with a wooden floor. Much more space ought to be given to the attendant than is usually done. We frequently find that he is provided with so small a compartment that he experiences the greatest discomfort when in it.

Framing.—The general framing, doors, &c., of the inside should, for preference, be of teak, as owing to its nature it is non-absorbent and proof against damp. The w.c. doors may be made so as to leave a few inches of space at the bottom above the ground, or the bottom panel may be in the form of louvres, so as to allow a current of air to circulate within. Items not to be forgotten are the provision in the w.c.'s of toilet-paper holders and hooks for coats. In the lavatories—mirrors, towel rails, coat-hooks, brushes and combs. In the attendant's cabin—cupboards for personal articles, storage for towels, soap, &c., and safe drawers for money, &c. A speaking tube should connect the attendant in the male and female sections.

Locks.—The locks to the w.c. doors may be either of automatic penny-in-the-slot type, or else locks having a registering number, in which case the user pays the attendant and the lock indicates the number of times the door has been opened. Bent coins have caused considerable inconvenience and damage to the former type of lock.

Lighting.—If the illumination of the convenience is by gas, care should be taken not to place the brackets too close to the prismatic lights, as the latter have been known to chip owing to the heat. The placing of the lights over the w.c.'s may be economically done by making one bracket serve two closets. Should electricity be used, it may be found convenient to so arrange the switches which are controlled from the cabin that certain of the lights may be switched off when not required. The staircases should be well lighted and an illuminated sign is sometimes fixed over the entrance. It is also desirable if the convenience be lit by electricity to also have at least one gas bracket available in case of the current failing.

Cost.—The convenience illustrating this article cost, without diversion of mains, £2,500, or 3*s.* 6*d.* per foot cube. R. J. A.

"Coombs" Pneumatic Ejector.—(*See* "Ejectors.")

Cosham Precipitating Tank. — This form of preliminary preparation tank of the "Natural" Purification Company was first adopted at Nuneaton. It may be constructed either on a circular or rectangular plan, and consists of a series of seven or eight separate compartments through which the sewage flows successively on its way to the outlet. The communications between the compartments are formed by "flocculent flues" or submerged exits, the object of which is to hold back floating matter. These, together with a number of cross walls, assist the precipitation within the tank and economise the chemicals employed. The sludge is removed from the bottom of the tank by a siphon terminating a little below the top water level within the tank.

Cremator (Jones').—This consists of a small independent high temperature furnace used in connection with town refuse destructors for the purpose of cremating and rendering harmless the objectionable fumes known as the empyreumatic vapours which arise during the earlier stages of the process of burning town's refuse. It was introduced in 1885 by Mr. C. Jones, M.I.C.E., of Ealing, but since that date considerable advances have been made in the process of disposal of refuse by burning mainly by the adoption of high temperature destructors of greatly improved design, thus rendering the employment of an independent cremator unnecessary. (*See* "Destructors.")

Crematoria and Columbaria. — **General Survey — Catafalque — Incinerating Chamber— Chimney Shaft—Furnaces—Columbaria—Site of a Crematorium—Cost of Crematoria.**

In the general arrangement of the plan of these buildings it is of the utmost importance that due regard be given to the relative positions of the chapel and the incinerating chamber, so that the coffin can be transported from the chapel to the crematory as quickly as possible. The chapel or hall should be planned with a minimum floor area of 1,200 super. feet. It will be found that this is the least permissible, for when the catafalque and necessary seating is provided there will remain little waste space. Provision should be made in the chapel for the reception of urns; they may be stored in niches in the walls, in the floor, or in the sides of the catafalque. In some cases a columbarium is provided under the chapel in the basement. This is found in the Liverpool Crematorium. A system of electric inter-communication between the chapel and the incinerating chamber is necessary; a bell-push placed either on the clergy's desk, or in the floor near it. This is provided so that he may inform the engineer in charge when the moment arrives for the body being removed from the chapel to the cremating chamber.

The Catafalque.—The catafalque or table upon which the coffin is placed during the service should be situated near the cremating chamber. In most of the English crematoria it is situated so as to project longitudinally into the chapel. This position has many disadvantages. It is far preferable to place the cremating chamber at the side of the chapel, so that the coffin passes out at the side, and the opening between the two apartments is not facing those who are assembled to witness the last rites.

The catafalque in general use is, in size, about 12 ft. long, 3 ft. 8in. wide, and 4 ft. high. The top is fitted with an apparatus worked by means of an endless chain, which conveys the coffin from the catafalque to the carriage in the cremating chamber. The coffin is transported to the furnace upon a carriage fitted with the same apparatus. The opening in the wall through which the coffin passes should be the full width of the catafalque, and about 2 ft. 6 in. to 3 ft. high. It should be fitted with a pair of wrought-iron doors, grills, or curtains.

Incinerating Chamber.—The incinerating chamber, which adjoins the chapel, is governed in size by the number and type of furnaces to be installed. When provision is made for one furnace only, then the chamber should have a minimum width of 20 ft. and 25 ft. in length. This will be found sufficiently large for any furnace. When two or more furnaces are provided then the superficial area will be increased in proportion. The cremating chamber should be well lighted and ventilated, and constructed of such materials as will allow of it being kept perfectly clean.

Chimney Shaft.—The chimney shaft should be situated in as close proximity to the cremating furnaces as possible; the internal measurements at the base being at least 2 ft. square. The shaft should be erected to a minimum height of 60 ft. A pilot fire is necessary at the base of the chimney shaft for any fumes not consumed in the furnace, to pass over. Many forms of pilot fires have been constructed, but, for general purposes, if a small grid is formed, having open bars for holding a small fire, it will meet the purpose for which it is provided. A small iron door and frame will, of course, be provided for access to the pilot fire.

Furnaces.—There are two types of furnace employed for burning human bodies—the reverberatory and the regenerative. In the former a tongue of flame coming directly from the flue is deflected on to the body. In the latter, gas is produced from coke, and then burnt in the chamber where the body is placed. Both methods are equally effective, but the latter furnace is much more costly to construct. It lends itself, however, to a more satisfactory means of collecting the ashes, and is in keeping with popular sentiment. There are four patent cremating furnaces on the English market, three of which are in use.

They are the "Simon" coke furnace, the "Tousil Fradet," a gas furnace, and the "Carbon Oxide"; another patent furnace is that of Messrs. Goddard, Masey, & Warner.

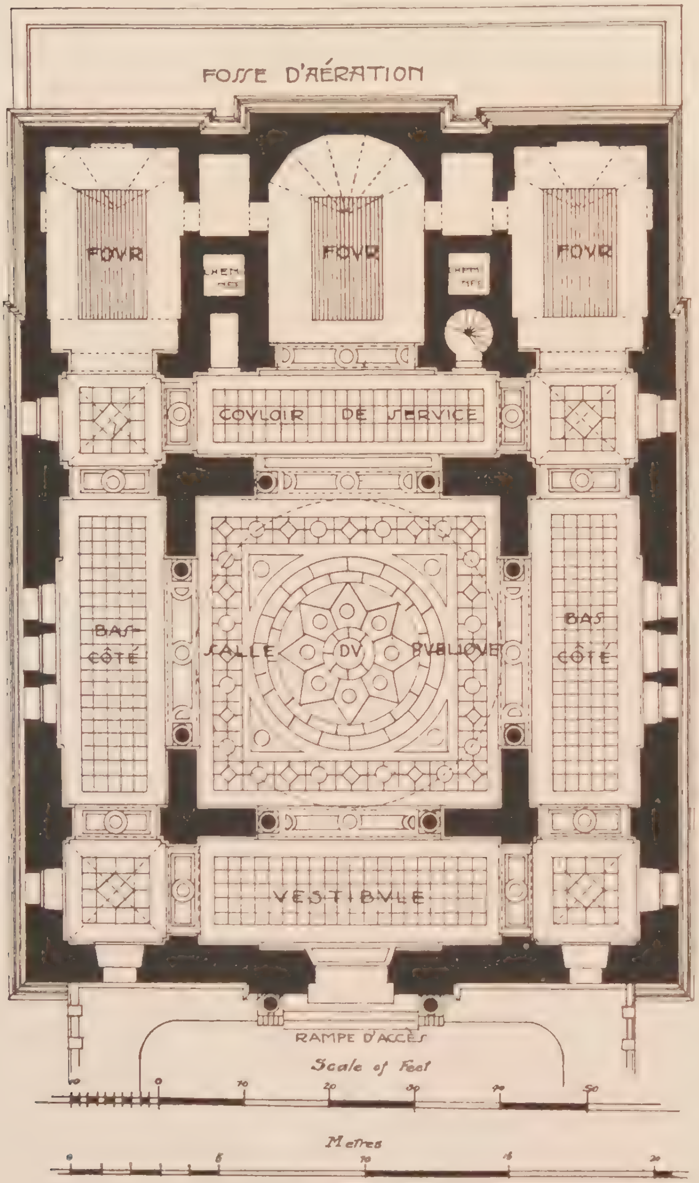


FIG. 1.—Design by M. Formége, Chief Architect Paris Municipality.

Messrs. Henry Simon & Co.'s furnace, which is in use in the principal crematoria of this country, is made in two distinct types. The older one is of the regenerative type, and consists of three chambers, the two lower of which are surrounded by air passages. The lower chamber contains a coke fire, and the upper or cremating one is that in which the body is reduced to ashes. The fire is lit some time before the apparatus is to be used, and is supplied with air in the usual way. Before the introduction of the coffin containing the body the air supply to the coke fire is greatly restricted, and after the body has been placed in the furnace a separate supply of heated air is introduced. Owing to the restricted air supply under the fire the product of combustion is largely carbonic oxide, which immediately on the addition of hot air burns into carbonic acid. The incinerating chamber is thus filled with gas of an intensely oxidising character, in a state of incandescence. The process occupies about one hour, at the end of which time there remains only the residue of the bones, consisting of grey pumice-like fragments. As the body is reduced to ashes, the remains fall through the grid into the chamber below. At the completion of the operation they are swept by an asbestos brush into an urn. Two inspection holes are provided at the head of the furnace; one overlooking the chamber containing the body, the other the chamber which receives the ashes. These are provided so that the engineer in charge may watch the progress and so regulate the working of the furnace to suit the progress of reduction. This furnace is erected in two storeys. When this furnace is adopted it is advisable to form an opening in the floor clear of the same, so that any expansion or contraction which takes place will in no way

affect the main structure. In the later type of the "Simon" furnace it is not necessary to have a basement, the whole being fixed on one level. This type is somewhat longer than the former owing to the firing portion being at the end instead of below. With this furnace the fuel used is coke only, and the heat is brought more directly into contact with the body. There is consequently a saving in the preliminary heating of the brickwork and flues previous to the operation. The construction is simple, and the furnace is built to withstand the contraction and expansion which takes place in all intermittently-fired furnaces. This furnace can also be arranged, with slight modifications, for heating with coal gas. The Carbon Oxide Company's furnace, which is heated by coke, is fixed in the Golder's Green and Woking Crematoria. Little information can be obtained of this furnace, but judging from inspection it appears to work satisfactorily. The construction is similar to those furnaces previously described. Messrs. Tousil, Fradet & Company's furnace is in use at the Leeds and Bradford Crematoria. This type of furnace has been in operation for some years in the crematoria at Paris, Rouen, Rheims, and Lyons. The heating is performed by gas, introduced through Bunsen burners at the rear of the chamber containing the corpse. The products of combustion pass out at the side near the front or entrance of the chamber. The hot gases are then conveyed along flues and pipes underneath the furnace in such a way as to highly heat the air supply to the burners, as well as a separate air supply that is arranged to enter the chamber at each side of the body at the later stages of the process, when desiccation has been completed and inflammable gases are being given off from the body. The air supply to the Bunsen

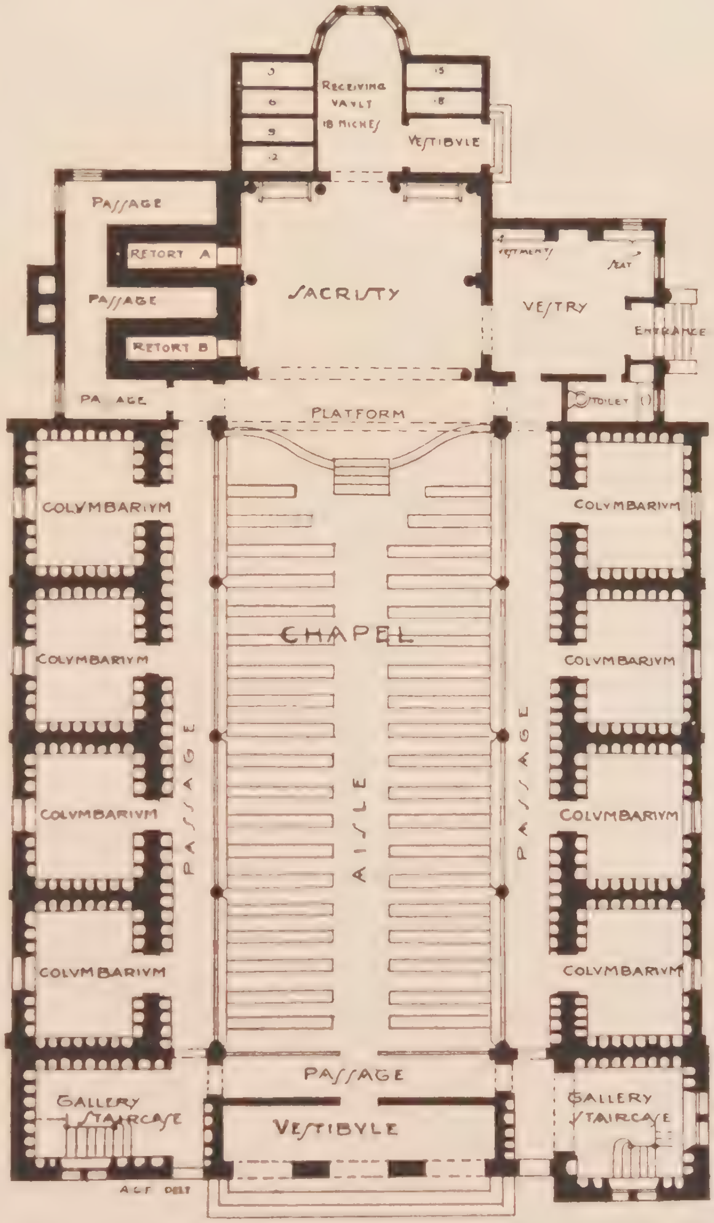


FIG. 2.—Crematoria, Portland, U.S.A.

burners is controllable, as is that supplied separately to the sides of the incinerating chamber. Messrs. Tousil, Fradet & Company also use a special mechanical apparatus for introducing the coffin into the

incinerating chamber, and for removing the ashes.

COLUMBARIA.—In planning a columbarium provision should be made for the requirements of the poor as well as for those who are in a position to pay large fees; little distinction, however, should be made between the two. Where the former niches are enclosed with plain stone or marble slabs, the latter will be finished with wrought iron, copper, silver, or gold grills. The niches or receptacles should be formed to hold from one to five urns in a single compartment. In constructing the niches, the materials employed should be such as will occupy the least amount of space. The urns in use are known as the "Box" or "Vase" shape; the first-mentioned measures 16 in. by 8 in., and is 8 in. high. The box urn being generally used, provision is made, with few exceptions, for this. The fronts of the niches are enclosed with marble or glass slabs, or grills made of iron, copper, or other material. Many beautiful examples of the latter are to be seen in the columbarium at Golder's Green, London. These grills are held in position by detachable copper or iron fittings. The interior of the niches may be plastered, distempered, or otherwise artistically decorated. When the grill of the niche is fitted with a lock, then the superintendent of the columbarium is supplied with a duplicate key, so that he may periodically clean the compartment, and if required, cover the urn with flowers.

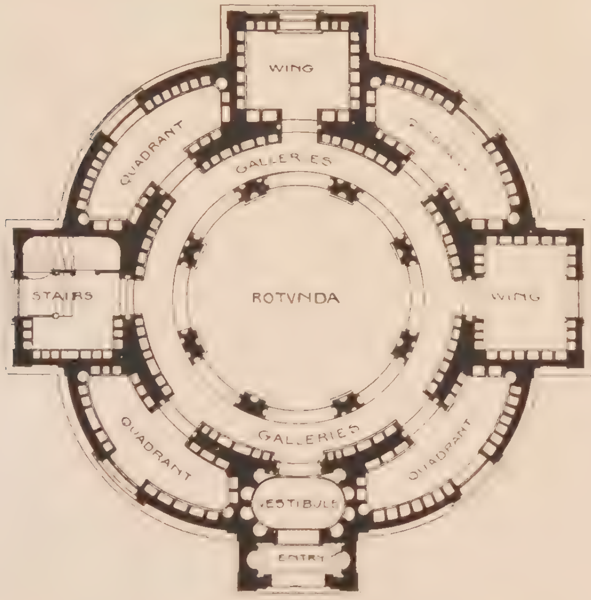


FIG. 3.—Columbarium, Oddfellows' Cemetery, San Francisco.

SITE OF A CREMATORIUM.—The Cremation Act of Parliament (2 Ed. VII., c. 8.), states that no crematorium shall be constructed nearer to any dwelling than 200 yds., except with the consent, in writing, of the owner, lessee, and occupier of such house, nor within 50 yds. of any public highway, nor in the consecrated part of any burial-ground of any burial authority. No crematorium shall be erected until the plans of the site thereof have been approved by the Local Government Board, and no human remains shall be burned therein until such time as the burial authority has certified to the Home Secretary that the crematorium is completed and properly equipped for the purpose of the disposal of human remains by burning.

COST OF CREMATORIA.—The cost of the crematoria in England has varied considerably; that at Woking cost £5,022; Leicester, including a chapel for inhumation services, and various other buildings, £13,830; Birmingham, £5,000; Liverpool, £8,000; Ilford, £7,000; while the municipal crematorium at Hull cost £2,700 only. A. C. F.

"**Cultivation Tank**" (Scott-Moncrieff).—In lieu of an ordinary septic tank, Mr. Scott-Moncrieff has used what may be described as a tank full of flints, with the object of providing anchorages for the cultivation of colonies of anaërobic bacteria throughout the mass of the sewage. In such a tank the sewage enters at the bottom and filters upwards through the stones which are carried on a grating, and escapes at the top by means of a suitable overflow, near the level of the inlet. This tank effluent is then distributed over the

uppermost of a series of nitrifying trays of boxes with perforated bottoms, and filled with coke of the size of beans. The system was first tried on a practical scale at Ashtead (1891), and has been adopted at the Caterham Barracks, and many other places at home and abroad. The separation of the anaërobic from the aërobic organisms is well provided for by this method of treatment, and importance is attached to this feature as forming the desired liquefaction of the sewage, and the satisfactory nitrification of the final effluent. For large installations, however, the question of cost would appear to be an important factor, inasmuch as it is cheaper to provide a given capacity in a clear tank than in the interstices of materials such as flints filled into the tank space; also, any undigested matter is more readily removed from the ordinary open tank than from a cultivation tank. The sewage would, in most cases, doubtless require screening and rough sedimentation before passing into the cultivation tank.

Dale's Muriate of Iron Process of Sewage Purification.—This process employs a concentrated solution of perchloride of iron for the disinfection and deodorisation of sewage.

Damp Buildings, prevention of.—The first thing is to obtain a fairly dry site, or to drain it as described further on, under the heading of sub-soil drainage. If the soil is retentive of moisture, the walls should rest on lias lime or Portland cement concrete, to retard the rising of moisture, and the whole site between the outer walls should be covered with similar material, 6 in. thick, the composition of which has already been described. It is generally considered advisable before laying the concrete to put 3 in. or 4 in. of good brick rubbish over the surface of the ground and lightly ram it so as to leave it in a permanent porous layer, but there is some doubt as to its actual utility. The inner cross walls and sleeper walls may be built on this layer of concrete.

Walls.—The basement or semi-basement walls may be protected from the external earth in contact with them by a layer of bitumen, or asphalte, or even by tarring, as in Fig. 1, or by making a cavity wall as Fig. 2. Where there is no basement, a horizontal damp-proof course is inserted 6 in. above the ground level as in Fig. 3. The horizontal damp-proof course may be Callender's pure bitumen, Robinson's roll asphalte, patent asphalted sheet lead, a double course of slates in cement, or horizontally perforated glazed tiles. Where the walls are subject to spray, or a very moist atmosphere, they are built hollow, a 4½ in. skin being placed outside the ordinary wall and bonded to it as in Fig. 4. At the window and door openings, bricks must be bonded across the cavity in the wall; and over the top of the door and sash frames, sheet lead must be built in and carried beyond the woodwork on each side to prevent moisture dropping on it. The cavity must in all cases be ventilated by air-bricks, or perforated tiles, as shown at the bottom, and similar openings at the top of the wall. The brickwork should be composed of thoroughly well-burnt bricks and good mortar. An ordinary building brick should not absorb more than one-sixth of its weight of water when left in for 24 hours, and a foundation brick of best quality should not absorb more than 6 °/₀. Other means of preventing damp from passing through a wall are covering it with hanging tiles or slates, coating it with Szerelmey liquid or with Fluate, or painting it. At the top of a wall the moisture is prevented from travelling downwards by an impervious covering of stone coping, Portland cement coping, blue brick lumps, or brick-on-edge in cement, having underneath it a layer of slates or tile creasing. Projecting copings, cornices, window-sills, &c., must be throated on the under-side to throw off the drips of water clear of the walls.

Roofs.—The most usual coverings for roofs are slates and tiles. Slates are split off from a naturally formed clay rock with cleavage planes, and, when of good quality, absorb very little moisture. Stood in a pail of water

over-night to half their depth, the water should not have risen 1 in. on the face in the morning. Slates are of various sizes, the most general being Countesses 20 in. by 10 in., laid with a lap of 3 in., and a visible margin or gauge of 8 in. if head nailed, and $8\frac{1}{2}$ in. if centre nailed. The slates are laid to break joint, and the lap is the amount the tail of a slate overlaps the head of those in the course next-but-one below, as in Fig. 5. Corrugated pantiles are only used on common sheds as they absorb much water and are very heavy. Hard burnt plain tiles, about 10 in. or $10\frac{1}{2}$ in. by 6 in. by $\frac{1}{2}$ in., are generally used for house roofs. They should be slightly curved in the length so as to lie closely at the ends, and be laid with a lap of not less than $2\frac{1}{2}$ in. and margin of $3\frac{1}{2}$ in. to 4 in., as shown in Fig. 6. The pitch of a slated roof may be from 25° to 30°, but a tiled roof should be from 45° to 60°, as owing to the less lap there would be more tendency for moisture to get in, unless the pitch were increased.

Plumbers' Work.—The plumbers' work of a roof is of the utmost importance. The

Fig. 1.

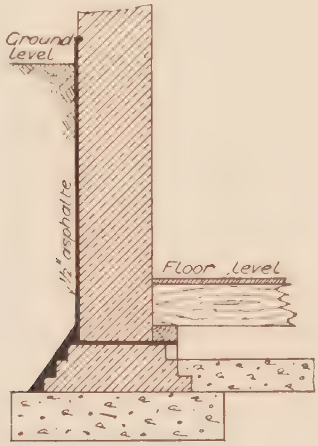
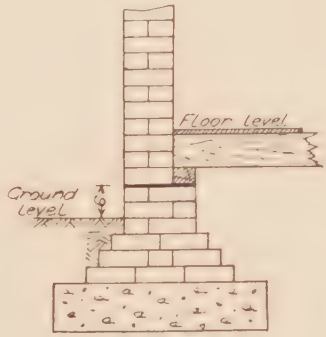


Fig. 3.



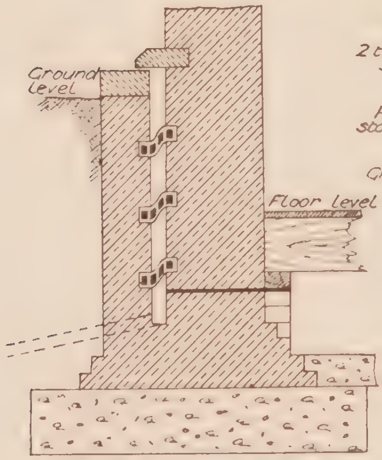


Fig. 2.

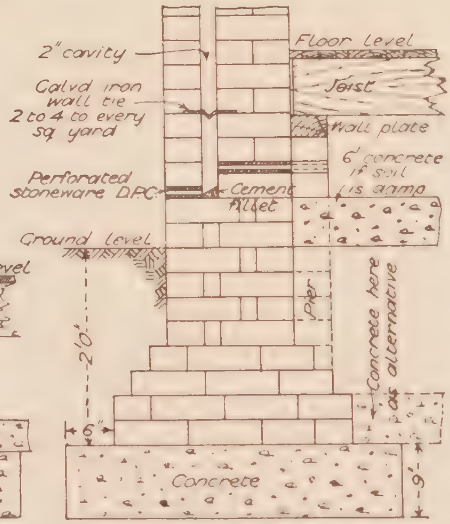


Fig. 4.

Fig. 1.—External Damp-Course. Fig. 2.—Cavity Wall.
Fig. 3.—Horizontal Damp-proof Course. Fig. 4.—Hollow Wall.

ridges and hips should be covered with, say 6 lb. lead dressed over 2 in. rolls, and the wings secured by tingles. The valleys should layer boards on each side. When a gable wall stops at the roof, the slates or tiles should overlap the verge by $1\frac{1}{2}$ in., and have a

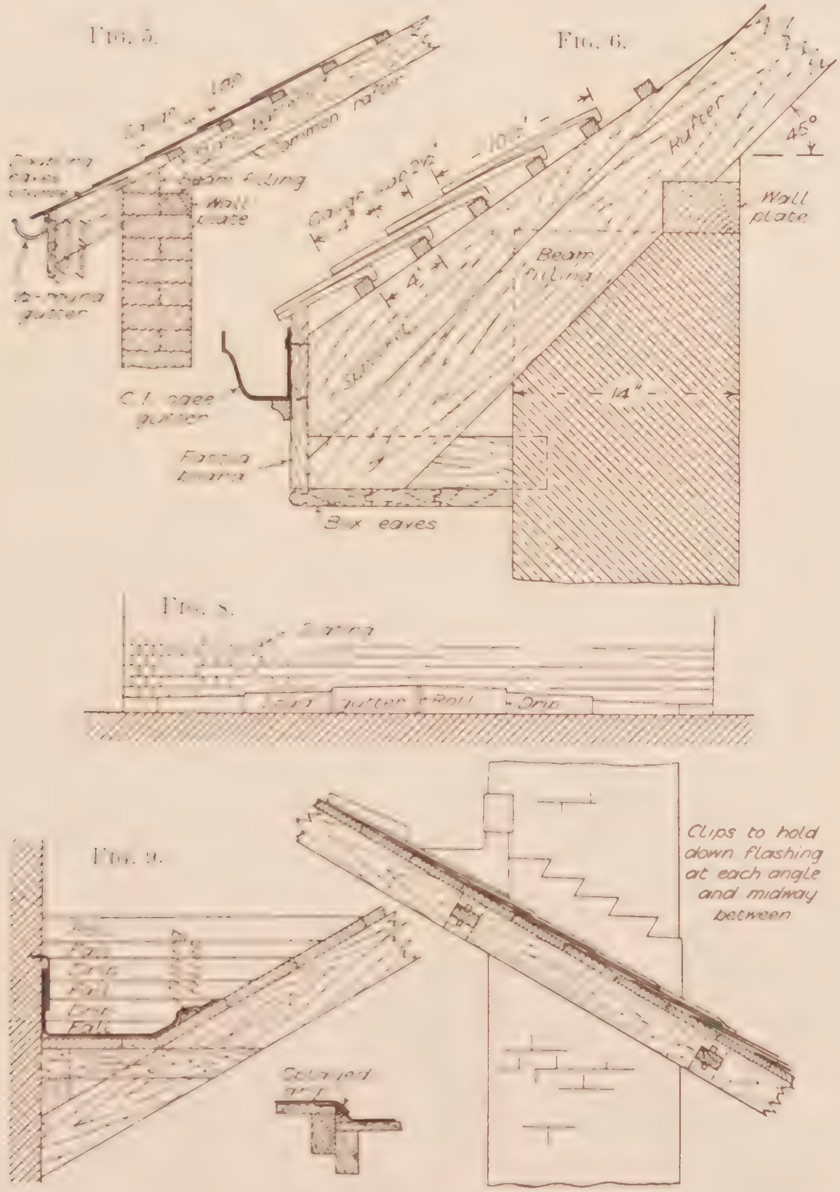


Fig. 10. Fig. 7.

Fig. 5.—Section through Slate Covering to Roof. Fig. 6.—Section through Tiled Roof. Fig. 7.—Stepped Flashing to Chimney Stack. Fig. 8.—Plan of Lead Parapet Gutter. Fig. 9.—Section through Lead Parapet Gutter. Fig. 10.—Section through Drip of Lead Gutter.

have 5 lb. soakers laid with laps between the slates on each roof plane, or a secret gutter should be formed with 5 lb. lead over the cement fillet underneath. When the gable is carried up to form a parapet wall above the roof 4 lb. lead flashing should be laid, 6 in.

on the slates and 4 in. up the wall, with an apron cover of 4 lb. lead $1\frac{1}{2}$ in. clear of the roof, and the top edge stepped into the courses of the brickwork. Similar flashing should be carried round chimney stacks, where they penetrate the roof, with a small gutter behind, as Fig. 7. The eaves of a roof behind a parapet wall are finished with a 7 lb. lead gutter on gutter boards and bearers, with a maximum width of 6 in., a fall of $1\frac{1}{2}$ in. in 10 ft., a drip at the end of every sheet, and roll at the highest part, when the gutter falls both ways. The plan will be as shown in Fig. 8, the cross section, to a larger scale, as Fig. 9, and the section through a drip as in Fig. 10. H. A.

Dams: Earthen, Masonry and Concrete.—**Earthen—Masonry—Concrete—Ferro-Concrete.**

Earthen Dams are used when a valley is to be converted into a natural or impounding reservoir. The valley should be as high as possible above the sea level, with a large gathering ground, and with a narrow neck between the hills, where the embankment to act as a dam could be placed. The subsoil should be an impervious rock such as granite, not chalk or limestone which is subject to fissures, or gravel which is freely pervious. In the latter cases, the reservoir would have to be lined with puddled clay. Borings or trial pits are necessary to ascertain the depth, nature and configuration of the subsoil and adjacent strata. Any surface material that can be excavated to deepen the valley may be used to help in the formation of the dam. The essential part of the dam is a central wall of clay puddle, punned in thin layers, carried down sufficiently into the strata below to prevent any leakage underneath, and extended well into the sides of the valley with the same object. The material for the embankment must be selected with care, and if it can be obtained from the bottom of the reservoir, this method has the advantage of increasing the capacity of the reservoir and reducing the cost of transit of the material. An earthen dam is usually cheaper than one of masonry or concrete, but it occupies a very large area of ground, and requires a very large quantity of material. It must be not less than 5 ft., and often 8 ft. to 10 ft. above the highest water level, surmounted by a roadway 20 ft. to 30 ft. wide in all, and the side slopes will depend upon the material used; generally they are 3 to 1 inside and 2 to 1 outside. The puddled clay wall stops short, say, 4 ft. below the surface to prevent the changes of atmospheric conditions affecting it, and particularly to prevent it from drying and cracking. At the level of the bed of the reservoir the puddle should be about one-third the maximum depth of water in thickness, tapering off to say half of this at the top and three-fourths at the bottom. The puddle should be well rammed in layers not exceeding 2 ft. thick, and in dry weather must be watered to secure adhesion between the different layers. Next to the puddle wall must be placed selected material retentive of moisture, and on the outside the best remaining material deposited in layers inclining towards the central wall. The outer slope is always covered with grass, either sods or seeds, to bind the material and prevent disintegration by the weather, and drained to prevent slips. If the top is not required to be finished as an ordinary roadway it may be turfed, with a slight fall each way to throw off the water. The inner slope may be turfed to the mean water level, but is more often covered with coarse flint ballast or stone pitching. The stone pitching varies from rough rubble set on end to properly squared sets, the chief use being to prevent damage by the wash of waves in a large exposed reservoir. The same slopes are kept throughout the dam, but the depth and bottom width decrease as the ends are approached. The outlet from a reservoir is the most difficult part to arrange, a pipe through an embankment is extremely liable to cause failure from water creeping along its outside surface and washing away some of the material; the leakage may be very slight at first, but will rapidly

increase if neglected. The overflow from the reservoir must be by means of a masonry weir or bye-wash. The accompanying illustration, Fig. 1, shows a section through an earthen dam of the Glasgow Waterworks. The cost of the embankment of a reservoir may be from 6*d.* to 1*s.* per cube yard. The approximate cost of the whole reservoir, including every expense of earthwork, puddling, pitching, waste-weirs, valves, &c., but exclusive of land will be given in £ per million gallons by the formula $\frac{25,000}{25 + m}$, where m = contents in millions of gallons. Under unfavourable circumstances it may be 10% to 25% more, but favourable circumstances may reduce the cost to from 25% to 50% less. Sometimes the inner face of the dam is protected from the percolation of water by a bed of puddled clay under the protective covering, and in smaller reservoirs the banks are lined with concrete alone, or concrete with an intermediate layer of bitumen, as in Fig. 2, and with no puddle wall. In these cases the great difficulty is to prevent cracks in the continuous surface of the concrete which may be due to imperfect junctions between the work of different days, contraction of the cement in setting, different qualities of cement used on the same job, or slips or subsidences in the earth backing due either to insufficient consolidation, too steep an angle, or improper filling.

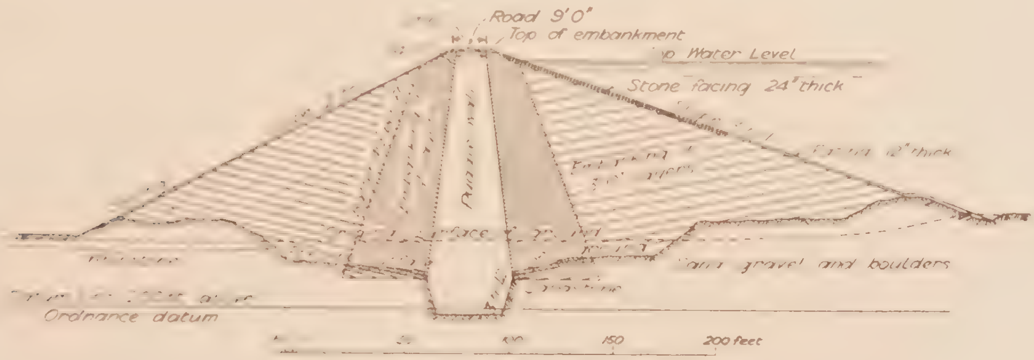


FIG. 1.—Section through Earthen Dam.

MASONRY DAMS.—An earthen dam resists the pressure of water by mere mass without any scientific disposition of the material being possible, but it is so extravagant of space that numerous cases arise where a solid structure must be built that shall have the minimum bulk. A masonry wall of parallel thickness is not suitable where the material must be economised. Under the thrust due to the pressure of the water the wall acts as a cantilever, the stress increasing from top to

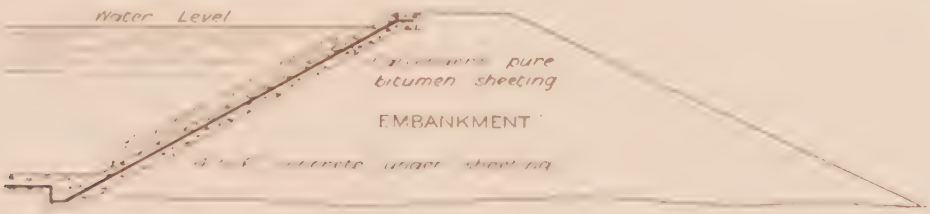


FIG. 2.—Reservoir Lined with Waterproofed Concrete.

bottom, the resistance must therefore be increased by adding to the thickness towards the base. In French practice a masonry wall with plain straight batter is considered sufficient, the top width three-tenths of the height, the inner face vertical and the outer face with such batter that the width of the base is seven-tenths of the height. In English and American practice the distribution of material is more nearly proportioned

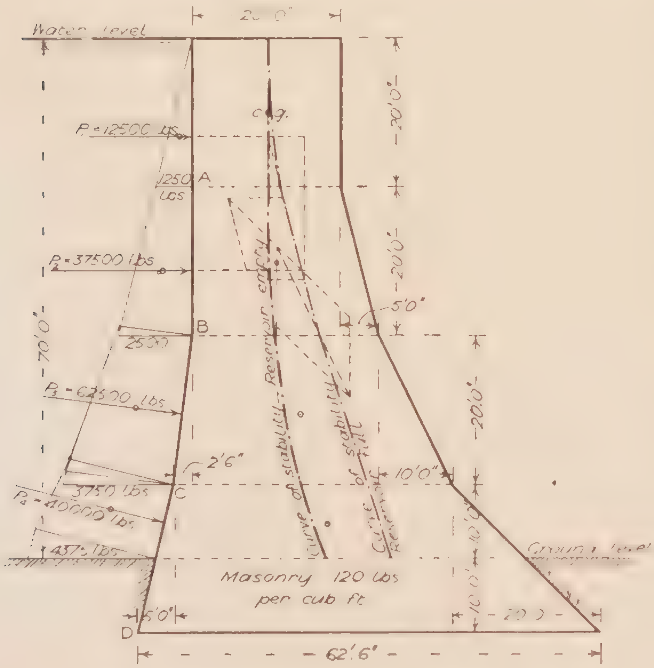


FIG. 3.—Principles of designing Modern Dam.

to the stress, allowing for the weight of the superincumbent parts as well as for the increasing thrust of the water as a greater depth is reached. The principle of designing and calculating the main stresses of a modern masonry dam is exemplified in Fig. 3, which shows a conventional section of a dam 70 ft. high. The curve of stability when the reservoir is empty will be found by first dividing the section into any convenient number of parts as shown by the dotted lines *A*, *B*, *C*, and *D*. Find the centre of gravity of each part, and through each centre of gravity drop a vertical line to cut the assumed base line of each part. The curve drawn through these points will be the curve of stability when the reservoir is empty. When the reservoir is full the method will be as follows: taking the part down to line *A* the pressures due to the head of water will be in the form of a triangle with a base at *A* of $62{\cdot}5 \times 20 = 1{,}250$ lbs. The total pressure will then be $\frac{20 \times 1{,}250}{2} = 12{,}500$ lbs. acting at right angles to back of wall through the centre of gravity of the triangle. This pressure must be combined with the weight of the part considered, and where the resultant cuts line *A* will be one point in the curve. The part from *A* to *B* must next be considered, and the pressures due to the head of water will now vary from 1,250 lbs. at *A* to $62{\cdot}5 \times 40 = 2{,}500$ lbs. at *B*. The total pressure acting through the centre of gravity of the quadrilateral will be $\frac{1{,}250 + 2{,}500}{2} \times 20 =$ 37,500 lbs., and this amount must be combined with the resultant from the first portion. The resultant thus formed is then combined with the weight of wall from *A* to *B*, and another point in the curve will be given where the resultant of the last step cuts line *B*. In a similar manner the other divisions of the wall may be worked out and other points found, through which the curve of stability when reservoir is full may be drawn. Other information may be given upon the same diagram, such as the maximum compression produced in the masonry at each level where the position of the curve has been found. Fig. 4 shows a cross section through the Vyrnwy dam with the principal figures of the stresses, and a pressure diagram below it showing the distribution of the load upon the foundations. This masonry dam with a flood water head against it of 129 ft. is a magnificent piece of engineering with considerable claim to architectural merit. Besides the main stresses

referred to above two others have received considerable attention in recent years, viz., the shear stresses and the upward pressures due to penetration of water below the masonry. The most important contribution to the subject of shear in masonry dams was given by Prof. Unwin in a series of articles in *Engineering* for April 21, May 12, and June 30, 1905, and the upward pressures have been discussed somewhat fully by correspondents in *The Engineering Record* during June and July, 1908. In consideration of the enormous stake in life and property connected with the design of dams, these matters are of very serious import, but they are rather beyond the scope of the present work.

Concrete Dams.—Fig. 5 shows a cross section through the spillway of a concrete dam about 34 ft. high in the Hudson Waterworks, New York. This dam was built in alternate 50-ft. sections at one time, with a tongue-and-groove tar joint between the sections. After the first lift of the forms had been filled, a 3-ft. layer of concrete was placed in one section on one day, then permitted to set a day while a 3-ft. layer was placed in an alternate section, after which another 3-ft. layer was placed in the first section, and so on. The surface of each layer was thoroughly brushed and cleaned, then wetted and covered with a thin coat of 1 : 2 Portland cement mortar before the next layer was placed. The concrete used in the dam was mixed quite wet in the proportion of 1 part of Hudson Portland cement, 2·8 parts sand, and $5\frac{1}{2}$ parts broken stone, these proportions having been

Fig. 4.

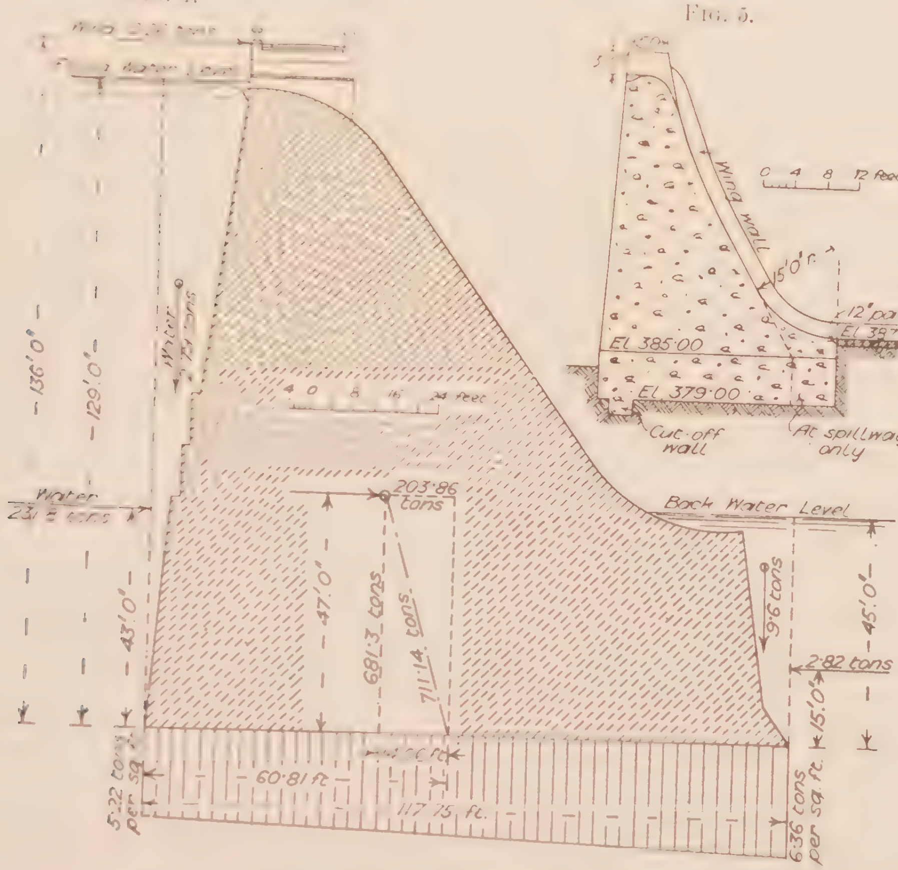


Fig. 4.—Section of Vyrnwy Dam. Fig. 5.—Section of Spillway of Dam.

found to give a slight excess of fine material. The sand was found to contain from 6 to 8 °/ₒ of loam. Thorough tests were made to discover, if possible, the effect of the presence of the loam, and, as good results were obtained in the tests, the sand was used. In the early part of the work the broken stone was screened, but the greater part of the concrete was made with crusher-run broken stone, in which the largest pieces did not exceed $2\frac{1}{2}$ in. in their greatest dimension.

FERRO-CONCRETE DAMS.—The Ambursen Hydraulic Construction Co. of Boston, Mass., give a remarkable section of a reinforced

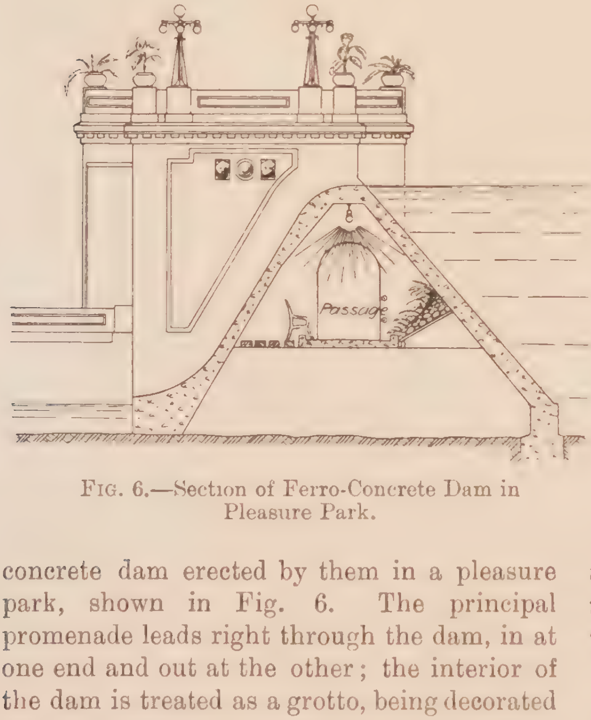


FIG. 6.—Section of Ferro-Concrete Dam in Pleasure Park.

concrete dam erected by them in a pleasure park, shown in Fig. 6. The principal promenade leads right through the dam, in at one end and out at the other; the interior of the dam is treated as a grotto, being decorated with rock-work, moss, ferns, &c.; the stiffening division walls are perforated by arches, seats are placed in each bay, and the whole is lighted by electricity. The main point about such work is that it must be not only strong, but must be waterproof; to obtain this the mixture must be rich in cement, not leaner than 1 : 2 : 4, with fine aggregate and plenty of water. Lime has been added to the cement used in mixing concrete for reservoir walls with the view of preventing the percolation of moisture and rendering the wall waterproof. There is some evidence that it is efficient, but until more is known about the action of free lime in cement it would be wiser to adopt more usual means, such as using a richer mixture of cement towards the face, or protecting it with one of the bituminous compounds, externally or a little way in from the face. H. A.

Deacon's Meter.—(*See* "WATER SUPPLY.")

Deep Well Water.—(*See* "UNDERGROUND WATER," "WELLS," and "WATER SUPPLY.")

Deodorants, or substances which remove smells, must be carefully distinguished from true disinfectants, many of which, however, are also deodorant. To get rid of a bad odour or to mask it by a stronger one does not necessarily indicate that disease-producing organisms are at the same time affected, and mere deodorants are often an evil by causing a false sense of security. Charcoal and dry earth absorb most odours, but have little or no action on bacteria. On the other hand many perfumes and aromatic bodies not only mask bad smells but also cause oxidation and are inimical to bacteria, and therefore may act as real disinfectants, *but not in proportion to their odour*. In chlorine and oxone the two powers are strongly developed. (*See* "DISINFECTANTS.")

Destructors.—**General: the "Destructor System" of dealing with Refuse—The Variable Composition of Refuse—Quantity of Refuse—Different Types of Destructors—Accessory Plant—Dust-Catcher, Boilers, Economisers—Thermal Storage—Remarks on the Design of Destructor Plants—Recent Improvements in Destructors—Production of Steam Power—Money Value of Refuse Fuel at Combined Destructor and Electric Stations—Total Costs of Burning Refuse, including Capital Charges.**—The term "destructor" is applied to a high

temperature furnace specially designed for the disposal of town refuse by burning. The system was introduced about the year 1870, and has since been subjected to great modification and improvement. It may be said that during the past 40 years the destructor system has had its birth, has grown into maturity, and has latterly been pursued to an extent which has enabled the practice to be reduced to certain well-understood general principles. Many years of practical experience has led to the design of efficient types of destructors, has shown what is the true calorific value of average town refuse, so that manufacturers are now able to give definite and reliable guarantees of performance such as both users and makers may with a reasonable degree of certainty expect to realise. The mere disposal of the refuse is not, as a rule, the only consideration kept in view in a modern refuse destructor station. A complete installation for a population of, say, 50,000 persons may cost from £5,000 to £6,000 to erect, according to local circumstances, and, in addition to the destructor cells proper, usually includes machinery and plant for the removal and disposal of the residual clinker, for its crushing and manufacture into paving slabs, bricks, mortar, or other saleable products, also steam and engine power for actuating the various plant required at such a station. It will, therefore, be evident that the working expenses, maintenance, and depreciation of a fully equipped installation must necessarily be considerable, and that with the view of reducing this annual expense to a minimum it becomes necessary to turn to account any and every by-product or residual material which can be really diverted to profitable use.

The Variable Composition of Town Refuse.—The material dealt with in destructors is of variable composition. It not only varies widely in different localities, but the summer and winter supplies of refuse in any town is rarely of the same calorific value. A destructor installation must therefore be adapted to cope with this unavoidable fluctuation where a fairly steady and uniform demand for the surplus heat available for motive power purposes exists. The constituents commonly met with in the refuse include, ashes and cinders, small pieces of coal, dust, waste paper and cardboard boxes and packings, straw, shavings, rags, vegetable and animal matter, scullery and kitchen wastes, bottles and preserved food tins, broken crockery, glass, bones, &c. The amount of cinders, ashes, and coal is not large, and has a tendency to decrease of recent years, owing to the extended use of gas fires, and the consumption of ready-made artificially preserved tinned and bottled foods. Contrary to what may be expected, the house refuse of the poorer districts of a town very usually contains the largest proportion of cinders and coal, which obviously formed the most valuable parts of the refuse from a calorific standpoint. This is probably due to the greater extravagance or want of care of the poorer classes in the sifting out of cinders from their household refuse, and its retention for further use, and also to the fact that the refuse from these quarters is more strictly household refuse with a much smaller admixture of garden and vegetable waste. As may be anticipated, the refuse of the coal mining districts of the northern and Midland towns possesses greater calorific value than that of the southern and eastern counties, but the distinction is not always so marked as might be supposed having regard to the relative prices of coal in different quarters.

The quantity of refuse to be dealt with from a given population is a matter requiring investigation when designing a destructor installation. In London this amounts to from 4 to 5 cwt. per head per annum, or to from 200 to 250 tons per 1,000 of the population per annum. In the neighbourhood of the Metropolis varying amounts have been reported, viz: $2\frac{1}{2}$ cwt. per head per annum at Leyton, $3\frac{1}{2}$ cwt. at Hornsey, and as much as 7 cwt. at Ealing. In the north of England the total collected, exclusive of street sweepings, has been put at 8 cwt. per head per annum. On the average from 5 to 10 cwt.

per head per annum must be allowed for. The weight of refuse is also variable, and great discrepancy will usually arise in estimates based upon so many "loads" collected per annum. The "load" may range from 10 cwt. to 1 ton, though from 12 to 14 cwt. is commonly about the weight of an ordinary good one-horse load of average house refuse weighed in fine weather. Much depends on whether the refuse is wet or dry, and whether it is collected from shop properties, or residential quarters. Shop refuse is usually of a light character and consists largely of paper, shavings, boxes and packings, and is of but little calorific value.

A population of, say, 50,000 persons will produce domestic household refuse at the rate of about 40 tons per day. As it is essential that this material should be satisfactorily and economically disposed of day by day, it is of first importance that the furnaces and plant employed be of the most perfect type for the primary purpose of burning the refuse, without thereby giving rise to nuisance or inconvenience to the neighbouring public. The secondary object of the plant must be to take the fullest possible advantage of the heat given out by burning the refuse for the generation of steam. In that way the cost of collecting and disposing of the material may be reduced. Some general idea of what may be regained in this connection may be gathered from the following calculation:—Forty tons of refuse per day, or about 12,500 tons per annum, giving an evaporative efficiency at the rate of 1 lb. of water per pound of refuse (a result readily obtained in practice), will develop a steam-power of 1,400,000 I.H.P. hours annually, calculating upon a steam consumption for condensing engines of 20 lbs. of steam per I.H.P. per hour. Then, allowing 3 lbs. of coal as the fuel consumption per I.H.P. hour, this gives an equivalent of about

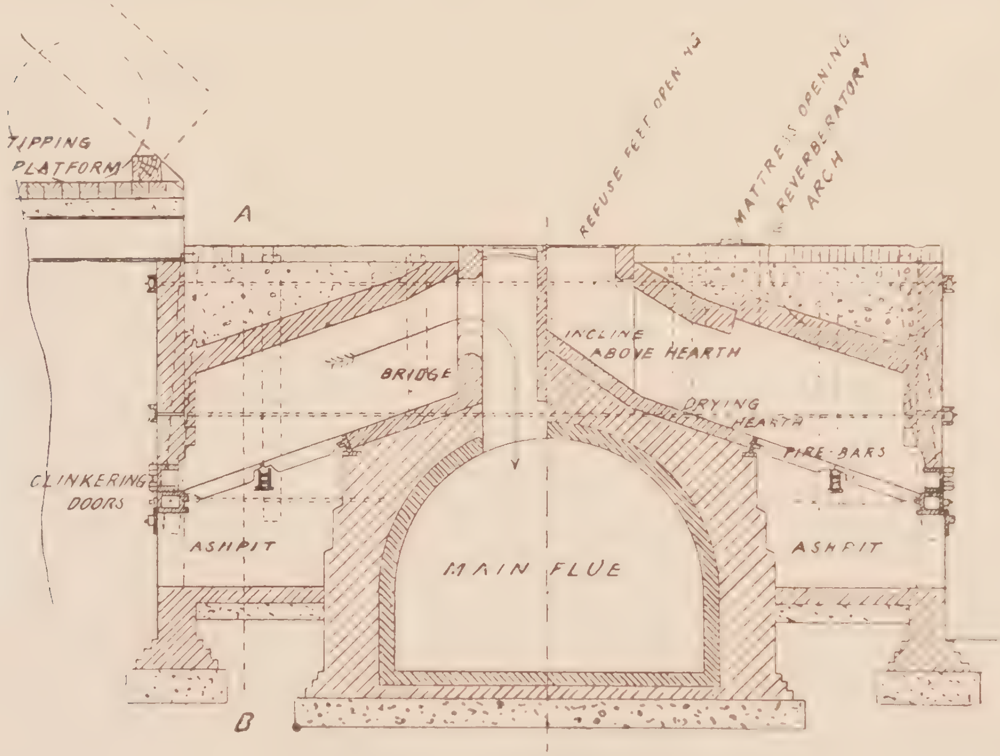


Fig. 1.—Section of Fryer's Destructor.

1,880 tons of coal per annum, showing the refuse in this case to be from one-seventh to one-sixth the value of coal for steam-raising purposes.

Different Types of Destructors.—Since Mr. Fryer erected his destructor in Manchester, in 1876, many different designs of furnace have been introduced, as experience has directed attention to numerous important points where improvements could be introduced. The principal furnaces to which attention should be directed are those of "Fryer," "Warner," "Horsfall," "Meldrum," "Beaman & Deas," the "Heenan" twin-cell, and the "Sterling" destructor.

Fryer's Destructor (Fig. 1), as already mentioned, is one of the earliest types, and for a long time formed the basis of several subsequent designs. It consists of a block of cells or furnaces, usually arranged "back to back" in pairs. Each cell measures internally about 9 ft. by 5 ft., and is covered by a fire-brick arch 3 ft. 6 in. in height above the grate area. The furnace floor slopes at an inclination of about 1 in 3, and the area of the fire grate is 25 sq. ft. This destructor ordinarily deals with from 4 to 6 tons of refuse per cell per 24 hours, and is known as a low temperature destructor. The outlets for the products of combustion are at the back of the cells near the refuse feed-opening, which is an undesirable arrangement.

Warner's Destructor (Fig. 2) is similar to Fryer's in general arrangement, but differs therefrom in many points of detail. It provides special charging hoppers, dampers in the flue, dust-catching arrangements, rocking fire-bars, and a modified position of the outlets for the escape of the products of combustion. The cells are 5 ft. wide by 11 ft. deep, the rearmost portion consisting of a fire-brick drying hearth. The grate area is 25 sq. ft., and the amount of refuse consumed varies from 5 to 8 tons per cell per 24 hours.

Horsfall's Destructor (Figs. 3, 4, 5) has been on the market for a great many years, and is well known both in this country and on the Continent of Europe. It was probably the earliest type to work at really high temperatures, and many improvements have been made in its design where experience has shown them to be necessary. It will be seen from the illustration that the general arrangement of the Fryer type has been followed in the Horsfall design; but that there are many

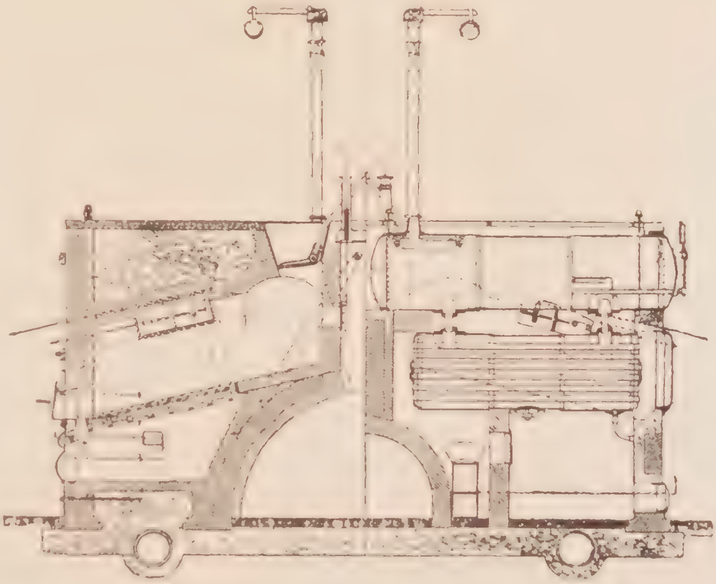


Fig. 2.—Warner's Destructor and Boiler.

important modifications, such, for example, as those of the arrangement of flues and flue outlets for the products of combustion and the introduction of a blast duct through which air is conducted to the closed ashpit. The feed holes are placed at the back of the furnace, whilst the flue openings for the removal of gases are situated at the front of the cell, so that the gases from the drying refuse pass on their way to the main flue over the hottest parts of the fire and through a red-hot reverberatory arch. The steam jet, a feature in the Horsfall furnace, forces air into the closed ashpit at a water-gauge pressure of

about $\frac{3}{4}$ in. to 1 in., thus producing a temperature of from 1,500° to 2,000° F. The blast air is conveyed on its way to the grate through cast-iron boxes at the sides of the furnaces, as shown in the figure, the boxes also having the further object of preventing the clinker adhering to the sides of the cells, the removal from which causes damage to the brickwork by the clinkering tools. The Horsfall furnace deals with from 8 to 10 tons per cell per 24 hours. Considerable improvements and additions in accessory details have been made in connection with this type of furnace during recent years.

removing the fine ash, and two Meldrum steam jet "blowers" are provided to each furnace capable of supplying any pressure of blast up to 6 in. water column. The pressure usually used does not exceed $1\frac{1}{2}$ ins. The furnaces are arranged for hand feeding from the front, but hopper feeding of the customary type can be adapted if preferred. The flue gases pass away to the boilers and from thence are further utilised in an air-heater or continuous regenerator consisting of cast-iron pipes from which the air is delivered through the Meldrum "blowers" at a temperature of about 300° F., thus assisting to keep up the temperature of the furnace and facilitate combustion. High-pressure Lancashire boilers of large capacity are usually provided for the accumulation, during periods of light demand, of a reserve of steam. Storage is obtained by using the difference between the maximum and minimum working steam pressure and the permissible fluctuation of water-levels in the boiler. From 50 to 60 lbs. of refuse per square foot of grate area per hour are consumed by the Meldrum furnaces, as compared with about 22 lbs. per

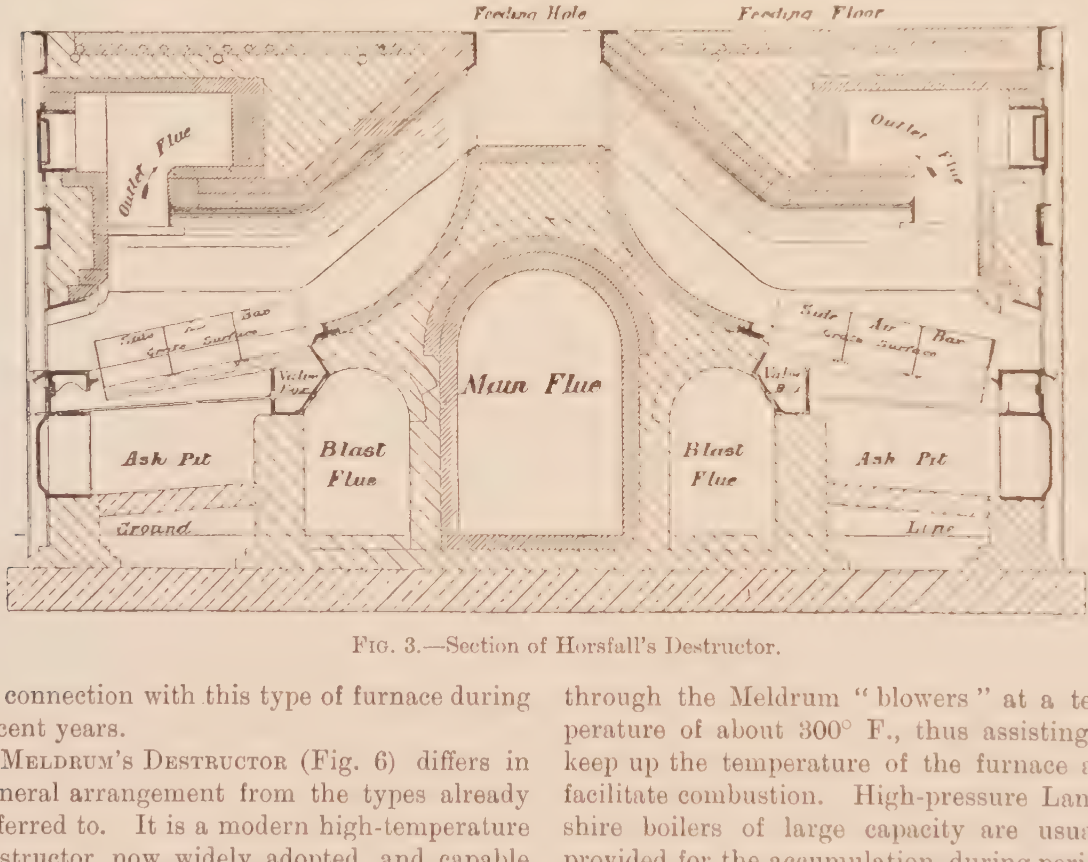


FIG. 3.—Section of Horsfall's Destructor.

MELDRUM'S DESTRUCTOR (Fig. 6) differs in general arrangement from the types already referred to. It is a modern high-temperature destructor, now widely adopted, and capable of giving good steam-raising results. This destructor is practically one long cell, fed and clinkered at four or five different furnace mouths, according to the number of grates installed, and by this means an approximately uniform temperature is maintained throughout. The ashpits are each closed air-tight by a cast-iron plate and air-tight doors for

square foot in the low temperature destructors. Installations of the Meldrum type have been largely adopted where a special feature of the destructor station has been to produce the utmost steam power possible for purposes of sewage or water pumping, or for electric light or power generation.

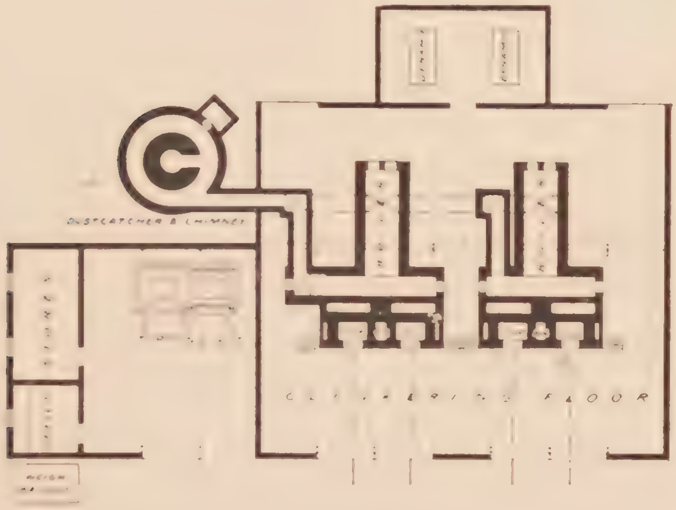


FIG. 4.—Section of 4-Cell Tub Fed Plant by Horsfall Destructor Co., Ltd.

BEAMAN & DEA'S DESTRUCTOR is another high-temperature furnace, the patents of which are now in the hands of Messrs. Meldrum Bros., of Manchester. The special features are the flat grate area of 25 sq. ft., and the sloping drying and feeding hearth immediately below the feed hopper on the tipping platform. At the back of the cells is a high temperature combustion chamber, placed between the cell proper and the main flue. A secondary air supply also meets the fumes as they pass over the fire-bridge. The destructor is fitted with a powerful air blast, and is generally installed in conjunction with Babcock & Wilcox water-tube boilers. This destructor will consume about 20 tons of refuse per cell per 24 hours, and is a good steam generator.

"HEENAN" TWIN-CELL DESTRUCTOR (Figs. 7, 8, and 9) is one of the most recent destructors, and is built by Messrs. Heenan & Froude, of Manchester. The standard arrangement of this destructor, with Lancashire boiler and regenerative apparatus, is shown in the plan (Fig. 7). In the section (Fig. 8) a water-tube boiler and hot-air duct leading to the regenerator is shown. A plant of this type is in use at Gloucester, consisting of two "twin-cells." A "twin-cell" comprises two furnace-grates, each of 39 sq. ft. in area, with a fire-bridge between. Each pair of cells are capable of cremating 25 tons of refuse in 24 hours, and are worked together. A maximum amount of clinker of 25 % of the refuse is guaranteed. The furnaces work at a temperature of over 2,000° F.: that of the flues before the boilers is from 1,400° to 1,800°, and after the boilers from 400° to 700°. One Babcock & Wilcox boiler is provided to each pair of cells, and the weight of water evaporated from and at 212° F. per pound of refuse burned is from 1·25 lbs. to 2 lbs. Forced draught is produced by an electric fan of 12 B.H.P., running at 950 revolutions per minute. About 125 H.P. is obtained from the refuse when burning 150 tons weekly. The cells are fed through an iron shoot at the back, and the clinkering is done from the front of the furnace. The cost of the destructor was about £4,150.

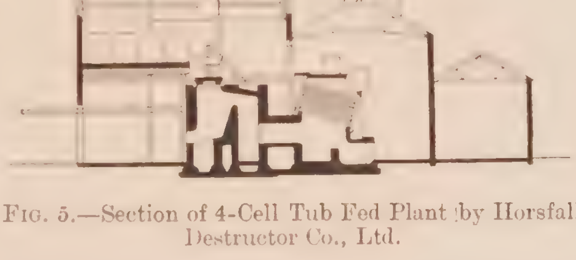


FIG. 5.—Section of 4-Cell Tub Fed Plant by Horsfall Destructor Co., Ltd.

The "Sterling" Destructor has of recent years been installed at Hackney, Bermondsey, Gravesend, Heston and Isleworth, and other places. The destructor and electricity works inaugurated at Hackney in 1901 are amongst the largest combined destructor and electric stations yet put down. The estimated cost of the destructor alone was £22,000 for dealing with about 38,000 tons of refuse yearly. The plant consists of twelve cells arranged in three groups, each group having a central supplementary combustion and dust-depositing careful attention, both from a sanitary as well as an economical point of view. The whole of each day's refuse is burned within the 24 hours. The electric energy consumed by the elevators and distributors is about ·35 of a kilowatt-hour per ton of refuse elevated, and the amount of the lift is 43 ft. from ground level to the storage bins. The forced draught is obtained from three centrifugal fans driven by 15 H.P. "Rhodes" motors. The guaranteed capacity of the destructor is 160 tons of refuse per day of 24 hours. The "Sterling"

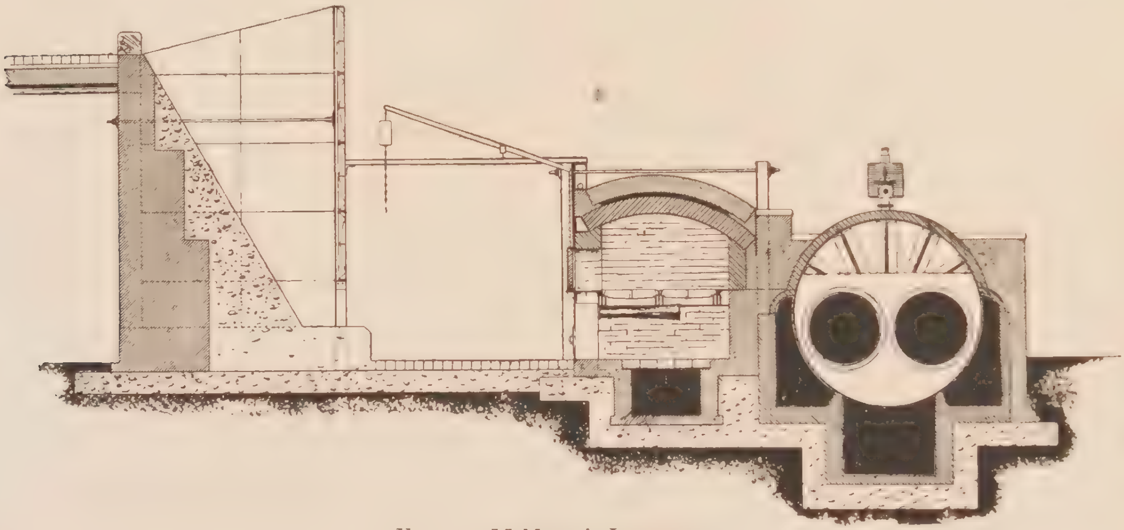


Fig. 6.—Meldrum's Destructor.

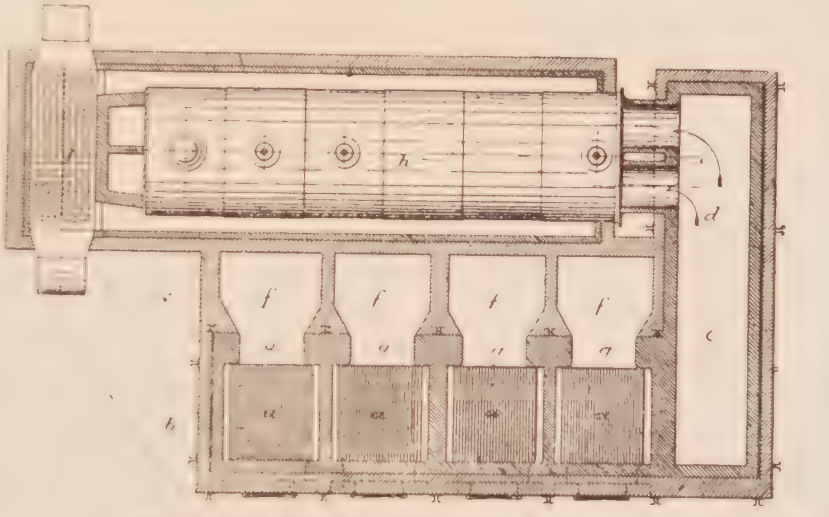
chamber, three Babcock & Wilcox water-tube boilers, fired by heat from the destructors, and built for a working pressure of 250 lbs. per square inch; three fans, each driven by an electric motor, for providing the necessary forced draught; three elevators, also driven by electric motors, for raising the refuse and delivering it into high-level refuse storage bins, whence it is drawn down as required into the cells; a large Green's economiser; and a complete range of flues and by-passes which permit the gases to be taken through the boilers and economiser, through the boilers alone, through the economiser alone, or direct to the chimney shaft without passing through either boilers or economiser. The best means of handling the refuse has received destructor may be generally described as a compound furnace, having at least two cells, each with a drying hearth, a grate, and a closed air-tight ashpit, combined with a special chamber placed between the cells. This chamber serves the purpose of a supplementary combustion and dust-depositing cell, and is made large enough for the reception of infected mattresses, bedding, and even of an entire ox. Calculating upon the basis of 1 lb. of steam per pound of refuse fed into the cells, the "Sterling" furnace (two cells), burning 2,800 lbs. of refuse per hour, will give 140 I.H.P. continuously per pair of cells at 20 lbs. steam per I.H.P. Steam-blast is not recommended by the makers, and the furnaces of this type

are assisted by forced draught produced by a fan.

Accessory Plant at Destructor Installations.—Much auxiliary plant is now in use for the complete equipment of a modern destructor station. Such accessories are mainly designed to ensure the following points:—(1) The complete combustion of the refuse and gases given off; (2) The avoidance of all possibility of nuisance in carrying on the working of the destructor; (3) the reduction of working expenses by labour-saving devices, and the introduction of means of utilising the residuals produced on the works, including the profitable employment of the surplus heat; (4) and the reduction of wear and tear and maintenance expenses generally. The utilisation of clinker from destructors has given scope for a variety of plant, such as mortar mills, crushers, slab-making machinery, for example, as that of Messrs. C. & A. Musker, Ltd., of Liverpool, and artificial stone-plant as made by Messrs. Fielding & Platt. Messrs. Musker have also introduced a brick-making plant, as now used by Bradford and Liverpool Corporations. The approximate cost of a 6,000-brick plant is £1,900, and of a 10,000-brick plant £2,300. The cost of production of the bricks averages from 12*s.* to 14*s.* per 1,000. For the purpose of manufacture of clinker into bricks, slabs, &c., the material as it leaves the furnaces must first be crushed to suitable sizes. A suitable machine for this purpose is the Cox & McTaggart clinker-crushing plant, consisting essentially of a pair of grooved rollers with removable faces made of specially hard metal and chilled, driven by heavy and powerful gearing.

At Kensington a plant costing about £6,000 has been installed for making road-paving blocks. The treated clinker, after crushing, is mixed with 15 % of Trinidad asphalte and a certain proportion of fine dust, and then pressed under two tons to the square inch into paving blocks 8 in. by 3 in. by 3 in. and 4 in. deep, for use upon secondary roads.

At Liverpool, trials have been carried out in the construction of labourers' dwellings of crushed clinker steel armoured concrete for walls, roofs, and floors. After mixture with cement the materials are filled into moulds to form large slabs representing a complete side, floor or roof of a room.



Heenan Twin Cell Refuse Destructor with Lancashire Boiler

Fig. 7.—Heenan's Destructor.

At Fulham a plant was put down by Messrs. Fielding & Platt at a cost of £2,365 for the manufacture of bricks and flags in connection with a 12-cell "Horsfall" destructor completed in the year 1900. The materials manufactured have been sold to the various departments at the following prices:—bricks 35*s.* per 1,000; paving flags 4*s.* per square yard; mortar 10*s.* 6*d.* per cubic yard, at the works.

Artificial slabs, concrete bricks, mortar, &c., are also made on a large scale at the Bradford Corporation Works, where nearly 60,000 tons of refuse are dealt with annually

by the destructors, at a cost for labour of about 11¼*d*. per ton.

An improved system for the easier removal of clinker from the furnaces has been adopted at Blackpool, Bradford, Hanley, Fulham, and several other places. The arrangement consists of an overhead railway with clinker buckets suspended upon a rail leading direct from each furnace to the cooling space or crushing machine. The handling of the clinker is thus reduced to a minimum, and the objectionable quenching of the hot material within the building is avoided.

The use of forced draught is an important and essential detail in all destructor stations. In the "Meldrum" system the air is delivered into a closed ashpit by means of a steam jet blower of special construction, used in conjunction with special made fire bars spaced only $\frac{1}{16}$ in. apart, and thus enables steam to be economically raised with materials containing only a small percentage of combustibles.

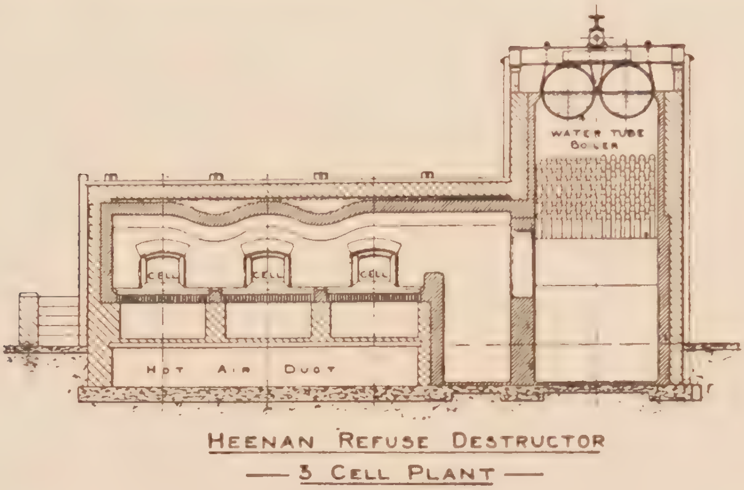


FIG. 8.—Heenan's Destructor.

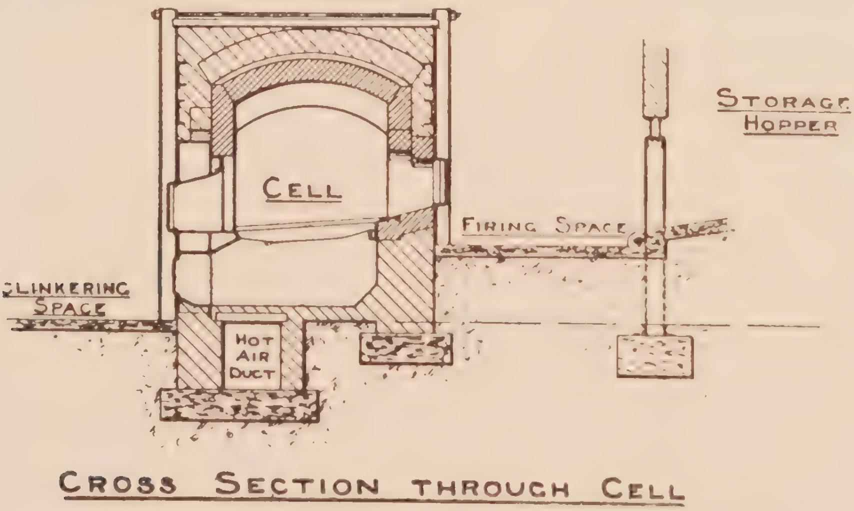


FIG. 9.—Heenan's Destructor.

The proportion of steam used in the forced blast is about 15 % of the total raised. At the set of six new cells built at West Hartlepool in 1903 was installed a system of forced draught on the Horsfall new "hot-blast system," in which each side air box in every cell contains its own separate steam blower, so that no condensation of the steam in the passages is possible. The air temperature in the ashpits is increased to over 400° F., which materially quickens combustion. A special form of superheater has also been adopted for heating the steam to the jets, increasing the efficiency of the blast and reducing the quantity of steam consumed.

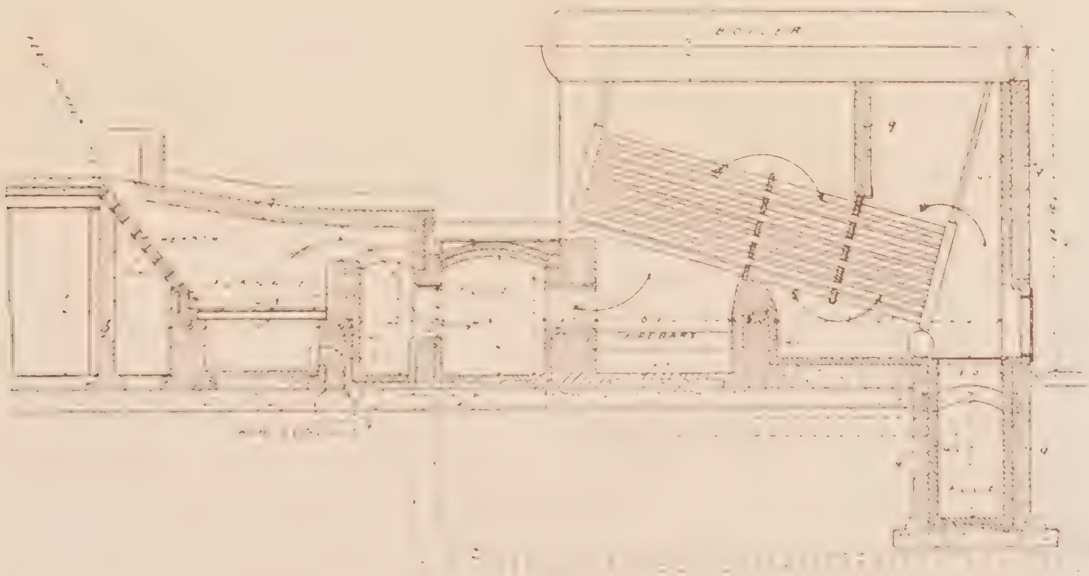


FIG. 10.—Leyton Destructor. Section through Cell and Boiler.

Improvements have been made of late years in the feeding arrangements to destructor cells in order to avoid the handling or storage of the refuse, to avoid nuisance, and to save cost of labour. Of these arrangements may be cited the apparatus of Boulnois and Brodie, the "feeding hoppers" of the Horsfall Destructor Co., and the special feeding arrangement adopted by Messrs. Meldrum Bros. for dealing with fish and slaughter-house offal. Unless there is some special local reason for adopting a hand-fed arrangement, such as the exigencies of the site, some form of top-feed closed hopper system is, on the whole, preferable, provided the mechanical devices adopted are quite simple in construction and work smoothly in daily use. The fires, however, should not be too suddenly fed with large charges of green refuse, otherwise the difficulty of maintaining a steady steam pressure will be increased, and some risk of imperfect combustion of gases incurred. With hand-feed at the furnace mouth the cost of an inclined roadway and raised tipping platform is dispensed with, and there is also an advantage, when combined with the continuous grate and divided ashpit arrangement, that the feeding in of small quantities of refuse does not very materially affect the temperature of the cell, as in the case of a large charge such as a ton or a load.

The "dust catcher" is an important feature in installations of the Horsfall type, and has for its object the prevention of the escape of fine dust from the chimney shaft into the atmosphere. It consists of an outer annular chamber and an inner well. The flue gases enter the outer chamber and swirl rapidly round it, thereby throwing off the suspended dust against the outer wall.

Clearing doors are provided for periodically removing the dust thus deposited within the chambers.

Other accessory details connected with destructor plants include counterbalanced furnace fronts, back-feeding or charging doors, water-sealed feed-opening doors, dampers, and furnace lining blocks.

The principal accessories for heat utilisation include various forms and settings of boilers, regenerators, economisers, and superheaters.

Boilers.—The boilers mostly used are of the Lancashire and the water-tube type. The Lancashire boiler, where there is a fairly uniform demand for steam, is a reliable steam raiser, and for steady work has much to recommend it. The thermal capacity is large, and a steady steam pressure can be maintained. Water-tube boilers, are, however, largely used in connection with destructors, as the steam power is very generally applied to the generation of electricity, in which connection the water-tube boiler is well adapted for coping with the sudden demands for steam often required in the generation of energy for lighting and motive power. Water-tube boilers have a small water capacity, a relatively large heating surface, and are, therefore, quick steaming boilers, but their small thermal capacity tends to unsteady steam production, and this class of boiler is liable to smoke with bituminous coal, so that smokeless fuel must be used. The use of pure water is also necessary to avoid incrustation in the tubes. The Babcock & Wilcox water-tube boiler has been largely used in connection with destructor stations, and has been found well suited to the work. The Stirling boiler is also employed in a similar connection.

Economisers, Regenerators, &c.—To secure the full value of available heat in the flue gases, in addition to using boilers of large heating surface as compared with their water capacity, it is necessary to provide "economisers" and "regenerators" through which the gases pass on their way to the chimney shaft. This cooling of the gases must not, however, be carried too far, otherwise the chimney draught will be impaired. A temperature of some 350° to 450° F. on entering the chimney may be regarded as satisfactory.

"Economisers" are placed in the main flue leading to the chimney shaft, and the hot flue gases thus utilised to heat the feed-water to the boilers. Green's and Hudson's economisers are much used for this purpose. The Green economiser is a flue-heated feed-water heater, by means of which the hot gases may be reduced in temperature from 650° F. to 350° F., and the feed-water heated some 150° to 250° F.

In the Meldrum system as installed at Sheerness, a Sugden superheater is placed in the down-take immediately behind the boiler, and arranged to give about 125° F. of superheat to the steam. Beyond the superheater is provided a Meldrum's "regenerator," or continuous air-heater, so that in addition to actual steam-raising the hot gases are further utilised for superheating the steam, and then for heating the air supply for combustion up to a temperature of about 350° F.

Thermal Storage.—The object sought in the storing of heat energy is to accumulate surplus heat during hours of light load, as, for example in electric central station work, so as to utilise this stored energy through the hours of towering peak load. The thermal storage installation originally put in at the Shoreditch combined destructor and electric light station was subsequently altered to store the hot feed-water instead of storing the actual steam, as was originally intended, and in this modified form has done good service. In 1904 an installation of thermal storage was put down by the Kensington and Knightsbridge and the Notting Hill Electric Light Companies for the purpose of increasing the capacity of their plant at their joint station at the Wood Lane Works. Large hot water-feed cylinders were placed over the steam drums of the existing water-tube boilers and immediately below the

water storage tanks. The main idea of the system is to increase the rating of the boilers at the hours of peak load by feeding the boiler with water at boiler temperature during those hours, this water having been previously heated to the desired temperature by live steam during the hours preceding the peak.

Remarks on the Design of Destructor Plants.—The proper design and capabilities of the refuse destructor and its accessory plants have not been well understood until within comparatively recent years. The utilisation of refuse as fuel is an essentially practical subject and one in which every "improvement" must be submitted to a prolonged practical test before it can be pronounced as good. The best results of to-day are obtained through a knowledge of the failures and defects of the past. Like most mechanical apparatus and inventions, that destructor plant is best which is simple, strong, and easily worked, if combined, of course, with efficiency. It would be unwise to lay down any hard and fast rule as to a particular type of plant as being absolutely the best for all cases and localities. Due regard must be had to the conditions of the case and local requirements. The choice of plant and the general design of a station requires to be entrusted to an engineer experienced in such matters in order to ensure the best results. The following general observations, however, will be a guide:—

The temperature in the cells must be sufficiently high to reduce the refuse to an entirely innocuous clinker, and all vapours given off should pass through an adjoining red-hot cell, or through a chamber whose heat is maintained by the ordinary working of the furnaces themselves to a temperature of from 1,500° to 2,500° F., so as to prevent the escape of noxious gases.

To maintain a uniformly high temperature, the destructor requires to be so worked that whilst one set of cells is recharging, another set is at a full red heat.

The furnaces and plant require to be strong, simple, and easily worked without stoppages, and should contain no mechanical complications. The installation should withstand variations of temperature and readily admit of being repaired. The plant must admit of being understood and worked by stokers of average intelligence, so that its continuous working may be ensured, and that the cost of working may be kept as low as possible.

Clinkering and recharging requires to be done as speedily as possible to prevent the inrush of cold air, which would reduce the temperature of the main flues and the calorific efficiency of the refuse. Where boilers are provided for stoking with both refuse and coal, a system of dampers should be arranged so that when coal fuel is in use only the refuse cells may be shut off from the boilers; otherwise the cold air passing through the cells and into the coal furnaces will materially reduce the calorific efficiency of the coal.

The chimney draught must always be assisted by forced draught from fans or steam jet to the extent of from 1·5 in. to 2 in. of water-gauge pressure in the ashpit.

In districts where the question of nuisance from the chimney shaft is of importance, boilers must not be placed immediately over a furnace in such a way as to present a large cooling surface to the gases, for then their temperature would be reduced before they have been rendered wholly innocuous.

If steam power is an important part of the system, ample boiler capacity and hot-water storage feed tanks should be provided; also the flue gases may be utilised in heating the air supply to the grates and the feed water to the boilers. For a high fuel efficiency a large proportion of CO_2 should be sought in the cells, with as little excess of air or free oxygen as possible.

Considering the somewhat trying nature of the work, a destructor station should be worked in three eight-hour shifts where the plant is running continuously. A bath-room in connection with the works will be found not only a boon by the workmen, but a hygienic necessity.

In order to derive the full advantage of

good points of design, it is necessary that the furnaces and plant be carefully and intelligently worked, and the efforts of the firemen should be towards obtaining a good, hard vitreous clinker, and perfect cremation of the whole of the refuse without the escape of unconsumed vapours of any kind; also the inrush of cold air into the cells and flues must be avoided as much as possible, otherwise the calorific results obtained will be low. The great improvements which have taken place in the design and management of destructor plants have contributed materially to the carrying on of such works in the midst of populated districts with a minimum of inconvenience to the neighbouring inhabitants.

The introduction of a good forced draught and high temperature furnaces has enabled larger quantities of material to be dealt with, and with less risk of allowing unconsumed vapours to escape into the atmosphere.

The Cost of Burning Refuse differs widely, according to local circumstances; at Battersea the cost is as much as 2*s.* 10*d.* per ton, whilst at Bradford it is burned for about 6*d.* per ton. Under ordinary circumstances a cost of 1*s.* per ton for labour, supervision and small repairs is a fair average figure. The amount of refuse burned per cell per hour materially affects the cost of burning. For purposes of comparison the best way of stating the duty of different types of furnaces is to state the performance of the furnace in pounds per square foot of grate area per hour, as the furnaces have varying grate areas, and to give the consumption in tons per cell is sometimes apt to mislead. The ordinary low temperature destructor, working without forced draught, deals with about 20 lbs. of refuse per square foot of grate area per hour, and this gives, for a grate area of 25 sq. ft. each furnace, a duty of between 5 and 6 tons per cell per day of 24 hours. This consumption is low, and with forced draught may be greatly increased. The Beaman & Dea's furnace at Canterbury has been found to deal with as much as 77·5 lbs. per sq. ft. of grate area per hour, and the same type cell at Llandudno deals with 71·7 lbs. per sq. ft. per hour. The consumption in the Meldrum furnaces at Rochdale is 66 lbs. per square foot per hour. The amount passed through the furnaces depends largely, however, on the mode of stoking, upon the degree to which the material is thoroughly cremated, and the frequency of the removal of clinker. The amount of residue clinker produced is usually between 25 °/ₒ and 33 °/ₒ of the material dealt with. Its ultimate disposal is a question of considerable importance in built-up districts, where the ordinary outlets for the material are not available, as the cost of cartage or barging to the suburbs of the town is almost prohibitive in many districts, as is the case in Shoreditch, where the total residue amounts to 32·8 °/ₒ.

Recent Improvements. — Some of the principal improvements made in destructor installations during recent years, include:—

1. The use of high temperatures within the cells and combustion chambers and the reduction of cold air-leakage into the furnaces.

2. Increased durability of the furnaces under high temperatures, and the avoidance of defects caused by contraction and expansion owing to frequent variations of temperature.

3. The employment of hot-blast and forced draught, and the reduction of power used in its working.

4. The extraction of the full calorific value from the refuse, and the interception and utilisation by means of boilers, economisers, or feed-water heaters, superheaters, regenerators, hot-blast draught, &c., of all heat given off by its combustion, and its fullest possible application to the performance of profit-yielding work.

5. Improvements in the uniform maintenance of steady steam pressures and in the generation of high-pressure steam.

6. The practical application of "thermal storage" in the employment of hot water-feed cylinders, thus affording a certain elasticity of output of power.

7. Improvements in the handling of the raw refuse, in the stoking and charging of the

furnaces, and in the removal and disposal of clinker, fine ash, &c.

8. The reduction of working and maintenance costs by the employment of the various improvements mentioned; also, some reduction of initial capital for a given capacity of plant.

9. The employment of all possible means of full utilisation of residuals created at the works and of any marketable material occurring in the refuse.

10. Various sanitary improvements in connection with the handling and storage of the refuse, and the prevention of dust or smells from the chimney shaft and destructor station generally.

Production of Steam-Power.—Various recent destructor installations, where the production of steam-power is an important consideration, show that, on the whole, an evaporation of from 1 lb. to 2 lbs. of water per pound of refuse represents the full available calorific value of town refuse for power production, and it is not usual that this average can be maintained over long periods of working under ordinary conditions. A few of the comparatively recent power-using installations, taken at random, are—(1) the "Horsfall" system at West Hartlepool Electricity Works, Fulham Electricity Works, Accrington Electricity Works, and Beckenham Electricity Works; (2) "Meldrum's" system at Cleckheaton, Burnley, Darwen, Port Glasgow, Wandsworth, and Plumstead; (3), the "Heenan" system at Blackburn, Gloucester, and Wakefield; (4), the "Sterling" destructor system at Bermondsey and Hackney. The amount of power obtained per ton of refuse varies with the character of the material collected in the particular district concerned. Taking the average of the mean results of six towns in the vicinity of coal-producing areas in the North of England an evaporation of 1·6 lbs. of water per pound of refuse is shown, as against 1·32 lbs. average evaporation of six destructors in the South-east. The difference is, however, often much more marked, as the refuse in some towns is of an unusually rich character. At Warrington the Beaman & Deas furnaces are reported, after prolonged test, as generating 3 lbs. of steam per pound of refuse throughout the year, owing to the refuse containing some 60 % to 70 % of cinders. At King's Norton the average refuse has been analysed and found to contain 36·8 % of carbon, 7·3 % of oxygen, and 12·12 % moisture, and yielded 4,500 British thermal units of heat per pound, or nearly one-third the value of average Welsh coal. Ordinarily, average town refuse is found to contain from 1,500 to 3,000 British thermal units per pound, and to possess a calorific value of from one-tenth to one-fifth that of average good coal. At Llandudno, the refuse is of very low calorific value, especially during summer, and here the Beaman & Deas furnaces (as used at Warrington above mentioned) give an evaporation of only about ·7 lb. of water per pound of refuse. A low value was also obtained at Royton (Lancashire) where, upon careful calorimeter test, only 997 British thermal units were obtained per pound of refuse.

Money Value of Refuse Fuel at combined Destructor and Electric Stations.—For many years past there has been a growing confidence in the utility of modern destructors as power producers in addition to being mere destroyers of refuse as evidenced by recent combined installations at such districts as Liverpool, Nottingham, Wolverhampton, Preston, Hackney, Bermondsey, Fulham, Plumstead, Woolwich, and others. From recent results of several London combined destructor and electric stations it appears that the money value of the refuse fuel per unit of electric current generated varies from about ·7*d*. to ·9*d*. per unit, and that under ordinary working conditions from 20 to 40 units per ton of refuse are at present obtainable, but that over limited periods much higher outputs have been generated. However, in the investigation of the value of destructors to electric or other power stations one of the main difficulties is that of procuring trustworthy statistics on a uniform basis such as can be usefully compared one with another.

Total Costs of Burning Refuse, including Capital Charges.—The quantity, or rate, at which refuse is burned by a modern destructor commonly lies between 50 lbs. to 60 lbs. per square foot of furnace grate area, and the cost of dealing with the refuse on this system varies on the average as follows:—

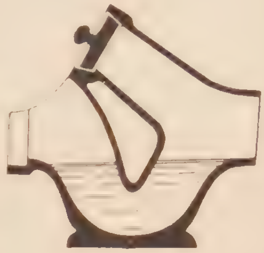
	Per ton of refuse.		
	s. d.		s. d.
Labour of burning and handling, including stokers, feeders, yardmen, &c.	0 8	to	1 10
Supervision, repairs, removal of clinker, stores, water, rates and taxes	0 6	to	0 9
Capital charges (interest and redemption)	0 6	to	1 9
Per ton of refuse burned	1 8	to	4 4

Advisability of combining Destructor and Electric or other Power-using Undertakings.—There has been much difference of opinion in many quarters as to the advisability of installing refuse destructors in conjunction with power-using stations of various kinds; but generally speaking, it may be stated that, where there is refuse which must be disposed of and works to which some form of motive power must be supplied, experience has shown that the modern refuse destructor is of a certain real commercial value as a power producer, and that, where suitable conditions exist, the outlay involved in its application to that duty is fully justified by the results obtainable, not forgetting at the same time, its useful sanitary function as a means of refuse disposal. (*See also* articles on "Refuse Disposal," and "Refuse Collection.")

W. H. M.

Detritus Tank.—(*See* "Sewage Disposal.")

Disconnecting Trap.—A trap fixed upon the outlet end of a house drain to break aërial communication between the drain and the public sewer, or other sewage outlet. Disconnecting traps are best fixed in manholes, in order that they may be readily reached. In the alternative a shaft reaching to the surface of the ground may be provided. It is desirable also that a sweeping eye be available on the outlet end of the trap, to afford access to the drain between the trap and the sewer, &c. The standing level of the water in disconnecting traps should be at least 3 in. below the inlet drain, in order that a cascade may be formed by sewage passing into it. This will have a tendency to break up accumulations in the trap, and greatly assist in keeping it clean.



Disconnecting Trap.

Disinfectants.—Disinfection in the modern sense may be regarded as having had its origin in the year 1862, when Pasteur, in response to an offer of the Academy of Science of Paris of a prize for "an attempt by means of suitable experiments to throw new light on the question of spontaneous generation," demonstrated the possibility of sterilising any substance whatsoever. Previous to the work of Pasteur in France and Koch in Germany little had been done in investigating the life cycles of bacteria with a view to ascertaining their relation to disease. Koch's method of isolating pure cultures of micro-organisms published in 1881, and his discovery of the tubercle bacillus in the following year, inaugurated a new era in preventive medicine, and for the first time in the history of that subject made the study of disinfection rational. In the light of the knowledge furnished by this and later bacteriological work the mode of action of disinfectants became plain; heat, whether dry or moist, destroyed infective bacteria; the problem of the resistance of spores was solved; and a significant distinction was drawn between antiseptics which inhibit the growth of microbes without destroying them and disinfectants which kill them outright. It was also found that deodorants for the most part which merely mask or absorb odorous gases and vapours possess

neither the properties of disinfectants nor of antiseptics.

In order to successfully carry out the work of disinfection it is clear that the life history, source, environment, and specific properties of the infective agent must be fully known, as also the nature and mode of interaction, chemical or physical, which obtains between it and the disinfectant.

The germicidal efficiency of a chemical disinfectant is often determined as much by physical conditions as by chemical structure; and to-day an efficient disinfectant, in addition to such germicidal efficiency, must be capable of penetrating various forms of organic matter containing bacteria, must be free from corrosive action on the skin and on metals, must be innocuous to man and the higher animals, must be homogeneous in all conditions of dilution or emulsion, and must largely retain its germicidal properties in the presence of organic matter.

Chemical disinfectants in the liquid state are obviously much more effective than in the gaseous or solid condition. The efficiency of a disinfectant liquid depends to a degree on the concentration of its active principle, and also on the particular form in which the active principle occurs. In the present state of knowledge it is impossible to state exactly how the micro-organism is killed. In certain instances it is probable that death occurs through coagulation of the protein of the cell, in others through its disruption. In solutions the degree of ionisation, and in emulsions the viscosity and size of the particles, influence the rate and completeness of penetration of the cell, and thus of the germicidal efficiency. The temperature of the disinfectant, within certain limits, influences directly the efficiency. Attempts have been made to reduce rate and efficiency of disinfection to mathematical form, but until very much more is known of the chemical and physical factors involved in this complex problem such work must remain unsatisfactory.

In the case of simple and stable acids efficiency is approximately proportional to the degree of acidity. In alkalies the nature of the metal forming the base and not the degree of alkalinity appears to govern germicidal efficiency. The efficiency of certain organic acids has been found to be inversely proportional to the molecular weight.

Sulphurous acid obtained from burning sulphur in a moist atmosphere, or from the liquefied gas, produces a slow disinfection of a very uncertain character, even in laboratory experiments. Although a committee of German experts unanimously condemned this disinfectant nearly a quarter of a century ago, certain British sanitarians still employ it, for what reason one cannot conceive other than that of the ancient witch doctor, that the more abominable the potion the more certain the cure.

Of the halogens and their compounds, chlorine is most commonly employed. It may combine directly with the protoplasm of the organism, thereby coagulating and killing it, at the same time decomposing offensive gases of putrefaction, such as sulphuretted hydrogen, phosphoretted hydrogen, and ammonias; or, which is the more common and important action of chlorine, in the presence of water it combines with hydrogen to form hydrochloric acid and liberates oxygen; this nascent oxygen kills bacteria and burns up putrescent organic matter. In a fluid like urine, which consumes large quantities of chlorine, excess must be maintained until the last germ is destroyed, that is, the smell of chlorine must be perceptible and persistent for some time. The age and vitality of the organism influence the length of time required for sterilisation. Intimate contact between the gas and the centre of the infected mass must be assured, and in this requirement chlorine in common with all gases largely fails as a disinfectant. In chloride of lime and hypochlorites the available or active chlorine is that present in the free state or as hypochlorite. Chloros is a solution of sodium hypochlorite said to contain 10% by weight of chlorine. In the process of disinfection by these bodies hypochlorous acid is formed from hypochlorite by

the addition of an acid or by spontaneous action of atmospheric carbon dioxide; the hypochlorous acid splits into hydrochloric acid and nascent oxygen, which latter acts as the disinfectant. The great fall of germicidal power which the hypochlorites experience in the presence of organic matter militates greatly against them as disinfectants.

Hermite solution may be regarded as the magnesian equivalent of chloride of lime. Sommerville and Walker (see *Lancet*, October 27, 1906) conclude that the available chlorine in this fluid diminishes on standing, is rapidly destroyed in the presence of organic matter, and does not later reappear. The Rideal-Walker co-efficient of the fluid was found to be 0·6; using urine as the diluent, with a minute's contact 0·075; and with urine as the diluent and an hour's contact, less than 0·01. The hypochlorites of this fluid, like all other hypochlorites, are unstable, and in presence of organic matter untrustworthy disinfectants.

Perchloride of mercury has been largely used in surgery, and is a powerful disinfectant; but it is also a powerful poison, doses of 0·2 gramme per diem rapidly causing disastrous effects. It dissolves in fifteen parts of water, and in less alcohol and ether. If the dissociation of metallic ions in a solution of mercuric chloride be reduced by the addition of a salt, such as sodium chloride, its germicidal power is likewise reduced. A dilution of 1 in 1,000 is recommended for non-sporing bacteria, and 1 in 500 for sporing bacteria. The biniodide of mercury is also used in surgery, is less poisonous than the perchloride, and is said to be of higher germicidal efficiency. Other salts of mercury in use are mercuric cyanide, mercuric salicylate, and mercuric thymolate—all poisonous, difficult of solution, and, as they coagulate albumin, unable to penetrate albuminous envelopes.

Where the organism is enclosed in a protein or fatty envelope those disinfectants which can be suspended in liquid soaps are to be selected, and it should ever be borne in mind that the solution or penetration of the protein or fatty envelope may require a much larger expenditure of energy on the part of the disinfectant than the killing of the micro-organisms within. In all such work it is obvious that the "oxidising" disinfectants (permanganates, peroxides, hypochlorites, &c.) are undesirable. In a set of experiments carried out by Sommerville and Walker a 20% solution of permanganate of potassium which gave a co-efficient of 50 in water dropped to 1·3 in a 1% solution of peptone, and a 10% solution of chloros, acting under the same conditions, fell from 21 to 0·2. Oxygen, ozone, and peroxide of hydrogen labour under like disadvantages.

Oxygen, the natural disinfectant, burns all organic matter into carbon dioxide, water, &c., and in the ordinary or molecular form acts slowly. It is highly active when liberated in the nascent state from permanganates, peroxides, &c. The intensity of its action, however, militates against its disinfectant properties when the bacteria which it is intended to kill are embedded in organic matter, seeing that it spends its energy on the latter. Ozone readily decomposes into molecular oxygen and nascent oxygen, and is mostly prepared for disinfection purposes from air by the passage of an electric discharge. Peroxide of hydrogen is readily prepared from a peroxide of an alkaline earth and an acid: $BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2$ This is a syrupy liquid which readily decomposes into water and nascent oxygen.

Of organic bodies the paraffin and aromatic series furnish the disinfectants most important in practice. Formalin, a 40% aqueous solution of formic aldehyde, is the most important of the paraffin group. It may be used in liquid or gaseous form, but the gas is practically useless unless precautions are taken to obtain in the room to be disinfected the necessary degree of moisture, temperature, quantity of formaldehyde (which should be not less, perhaps, than 100 grammes per 1,000 cu. ft.), and complete sealing from the outside atmosphere.

Of the aromatic series the best known is

phenol. It is generally stable in the presence of organic matter, but is poisonous and caustic, and for the disinfection of spores useless. Crude carbolic acid consists of cresols and higher phenols in various proportions, dependent on the source of the tar. Cresols are with difficulty soluble in water, and in alcohol or oil have little germicidal power; they are much depreciated in efficiency by proteins. The addition of salt solution or mineral acid enhances the disinfectant values of phenol and cresols, and the latter may be conveniently dissolved in alkalies. A number of saponified neutral tar oils, known commercially as soluble carbolic acid, soluble creosote, &c., is met with in practice, but the efficiency in all cases is low. Lysol appears to be a solution of cresols in fatty acid saponified with addition of alcohol. It produces a clear solution in water. Izal is described as a preparation of oxidised hydrocarbons obtained from coke ovens. It is much less poisonous and caustic than phenol, and has a much greater germicidal power. Cyllin is described as prepared from certain members of a new series of oxidised hydrocarbons extracted from coal-tar, and is emulsified so as to be miscible in all proportions in water. Its toxicity is extremely low, and germicidal efficiency high.

Cofectant, a still more modern preparation, is exquisitely emulsified and of high and constant efficiency. Its toxicity is negligible.

Disinfectant powders may have some value when they possess a soluble base, otherwise, except as deodorants, they are useless. The only practicable base is lime, and as this is incompatible with phenol, it is necessary to use a high class disinfectant of different type; such disinfectant may be found in the aromatic group. It must not be forgotten, however, that the germicidal powers of the best possible powders are necessarily small when compared with liquids.

Experimental work on the bacteriological standardisation of disinfectants during the past five years has brought to light the superior efficiency of certain emulsified coal-tar products. It is possible to prepare such emulsions so as to possess a germicidal efficiency fifteen or sixteen times that of phenol, when tested by the Rideal-Walker method, or ten to twelve times that of phenol, when subjected to the Sommerville-Walker test.

Until recently the merest empiricism has characterised the use of disinfectants. In future, discrimination will be used in selecting a suitable type of disinfectant for a particular form of work, and in order to obtain the best results all the conditions attaching to the work to be done will be intimately studied. It has been amply demonstrated that, except in a very few cases, the quantitative estimation of the so-called active chemical principle furnishes little information concerning germicidal efficiency. Previous to 1903, when Rideal and Walker brought forward their bacteriological method of testing disinfectants, too much attention had been paid to the quantity of chemically active principle present in disinfectants, whilst the form in which it existed was practically ignored; chemical analysis was accordingly the main criterion by which the value of a preparation was estimated. In bacteriology, as in all sections of biology, the estimation of effects produced on any unit or set of units by external conditions involves the careful consideration of a number of variable factors. But if in a given series of experiments one observer considers the time of application of the agent the only important factor, a second the proportion of culture to disinfectant, and so on throughout, no two results can be compared. Uniformity of procedure in every step of the investigation must be a *sine quâ non* where comparison of results is required. Rideal and Walker in their method lay it down as axiomatic that in selecting any particular process to be employed as a standard the following factors must be considered :—(1) Time of medication and incubation. (2) Age of the bacterial culture; the resistance of different micro-organisms varies in different degrees according to age. (3) Choice of medium and its reaction; broth cultures possess certain advantages

over cultures raised on solid media; the standard broth used for the growth of the B. typhosus possesses an acidity of + 1·5 °/₀. (4) Temperature of medication; within certain limits the higher the temperature at which disinfectants act the greater the germicidal efficiency. (5) Temperature of incubation; all organisms have an optimum temperature of growth at which temperature they are most vigorous. (6) Variations in vital resistance of the same species; sub-cultures of organisms on different media possess different degrees of resistance, as do also cultures obtained from different sources. (7) Variations in vital resistance of different species; for the most part disinfectants give different co-efficients when tested against different organisms. (8) Proportion of culture to disinfectant; the slightest deviation from uniformity in this factor makes the test worthless.

The efficiency of the disinfectant is expressed in terms of phenol doing the same work as the Rideal-Walker co-efficient. Whilst much has been written on methods of estimating available chlorine in bleaching powders, crystallisable phenols, cresols, tar oils, and water in preparations of carbolic acid, &c., &c., it cannot be too emphatically stated that all such tests are vain, and that direct appeal to bactericidal powers alone avails. (See section dealing with Bacteriological Examination of Disinfectants.)

With a view to imitating conditions that obtain in practical disinfection, Sommerville and Walker, in 1906, attempted to grow the B. typhosus in various forms of sterile organic matter, such as urine, blood, blood serum, mucin, gelatin, pus, &c., and then to add the various disinfectants in suitable dilutions to measured quantities of these organic media, and finally to plant out in broth after the manner of the Rideal-Walker method. But several trials demonstrated that the *B. typhosus* grew so feebly in these media that it was impossible to obtain uniform results. Later they pointed out that uniform results could be obtained by diluting the disinfectants under test with an emulsion of ·5 °/₀ gelatin and ·5 °/₀ rice starch. The starch was used to meet the influence of adsorption. The presence of this amount of animal and vegetable matter lowered the co-efficients of different disinfectants to different degrees, but in each case always to the same degree.

It is not to be concluded that the figure obtained (Sommerville-Walker co-efficient) indicates in any measure the quantity of disinfectant to be used in any given case; it merely shows the relative fall of co-efficient of a disinfectant under the conditions of admixture with organic matter described, as compared with phenol under the same conditions. In this, as in many other problems in which exact quantitative data cannot be obtained, a liberal use must be made of "the factor of safety." D. S.

Disinfection Stations and Appliances.—1. Local authorities have power to provide and equip disinfection stations and to disinfect free of charge any articles brought there for the purpose. They must exercise their power to disinfect or destroy any articles as to which the Medical Officer of Health or any other legally qualified medical practitioner certifies that their disinfection or destruction would tend to prevent or check the spread of any dangerous infectious disease, unless the master or owner of the house undertakes the duty within 24 hours from receiving notice from the local authority and carries out his undertaking. For the purpose of such disinfection the local authority may enter any premises by day (6 a.m. to 9 p.m.). The disinfection must be carried out at the cost of the local authority, under the superintendence of its Medical Officer of Health, and compensation must be given to the master or owner of articles which have been damaged unnecessarily in the process of disinfection. On the application of any person, local authorities may pay the expenses of disinfecting any bedding, clothes, or other things which have been exposed to infection, provided such disinfection is carried out by the local authority or under its direction.

On notification from any person that a book in his possession belonging to a public or circulating library has been exposed to notifiable infectious disease, the local authority must cause such book to be disinfected or destroyed, paying to the proprietor the value of any book destroyed. When a person suffering from a notifiable infectious disease has been driven in a public vehicle without the knowledge of the owner or driver that the person was so suffering, the owner or driver may require the local authority to disinfect the vehicle and its contents free of charge. The local authority may provide apparatus for destruction of vermin, and allow it to be used free of charge by any persons declaring themselves to be infested with vermin. Such apparatus consists essentially of a steam disinfector for clothing and baths for persons.

Ships or boats in rivers, harbours, or other waters within the jurisdiction of a local authority, are reckoned for disinfection purposes as houses, the master, or other officers in charge, being deemed the occupier. If not within the district of a local authority the Local Government Board may prescribe a district to undertake the duty, and in default of such prescription it must be undertaken by the nearest district. Admiralty and War Office property are exempt from the jurisdiction of the local authority, unless by consent. The Local Government Board may authorise or require any two or more local authorities to combine for the purpose, *inter alia*, of disinfection.

In addition to the normal powers and duties of a local authority, of which the effect is summarised above, special regulations may be made by the Local Government Board on the occurrence of cholera or any other epidemic, endemic, or infectious disease, or on any part of England appearing to be threatened or being affected by any formidable outbreak. These regulations may be revoked or modified, and the period of their application extended or abridged; and the local authority of any district within which or part of which such regulations are declared to be in force must superintend and see to their execution, and appoint and pay any necessary medical or other officers, and do all things necessary. For practical purposes, a local authority has, therefore, to provide for the disinfection of all articles liable to retain infection, whether in normal times or during epidemics; and in view of the difficulty of ensuring proper disinfection of goods, such as rags used for industrial purposes, they may find it expedient to undertake such disinfection for themselves.

2. The construction of a disinfection-station should fulfil the following conditions: (*a*) The disinfection room should be divided into separate chambers for infected and dis-infected material respectively. No direct passage of men or material from the infected to the disinfected side should be possible except through the steam disinfector itself. For this purpose the room is divided by a solid wall or partition through which the disinfector projects in each direction. A window may be let into this wall to enable persons employed on one side to see and signal to those on the other. The best means of providing access from the infected to the disinfected side is to arrange exits on the side wall of each space leading into lobbies which communicate through doors with a bath-room fitted with a water-basin. Each of the lobbies has a set of overalls and felt slippers for each man, which he puts on as he passes into the corresponding side of the disinfection room, and takes off as he passes out from it, washing his hands and face as he passes through the bath-room. At the end of the day the clothes and slippers are passed through the disinfector and returned to their proper places. The use of overalls and of washing is of some importance in reducing the risk of disinfected objects becoming reinfected. Its chief value, however, lies in the fact that at the cost of comparatively little trouble it is an automatic drill for the disinfector attendants in the caution which they must exercise if their work is to be effective. (*b*) The space allotted to the infected side should be no greater than will

accommodate the goods to be treated, facilities for storing, and thus delaying their treatment, being undesirable. The disinfected side, in which the working fittings of the disinfector should be arranged, should be of ample size, with convenience for airing and storing disinfected objects. (*c*) The internal facings of all walls, floors, and ceilings should be smooth, impervious, free from angles and as far as possible from joints, unaffected by damp, and reely guttered and drained so as to allow of copious flushing. (*d*) All parts of the building should be well lighted; skylights should preferably be double to avoid the risk of condensation and dripping. The windows, &c., should be arranged to give thorough ventilation, but to avoid draughts in the neighbourhood of the disinfector and the disinfected clothes. It is convenient as well as desirable on other grounds to have two vans, one being reserved for collection of infected goods and the other for delivery of disinfected goods. Where this is practicable, the stables should be kept separate as in the case of the infected and disinfected sides of the disinfection room. All surfaces in a collection van should be waterproof and free from seams and angles, so that it can be thoroughly washed with a strong soap-disinfectant at the end of each day. Where only one van is used, or no separation is maintained between vans for collection and for delivery, the van after disinfection at the end of the day should be kept on the disinfected side. Where the van does more than one journey in the day, it must be washed with strong soap-disinfectant after each journey. The courtyards should be asphalted or concreted to allow of free flushing.

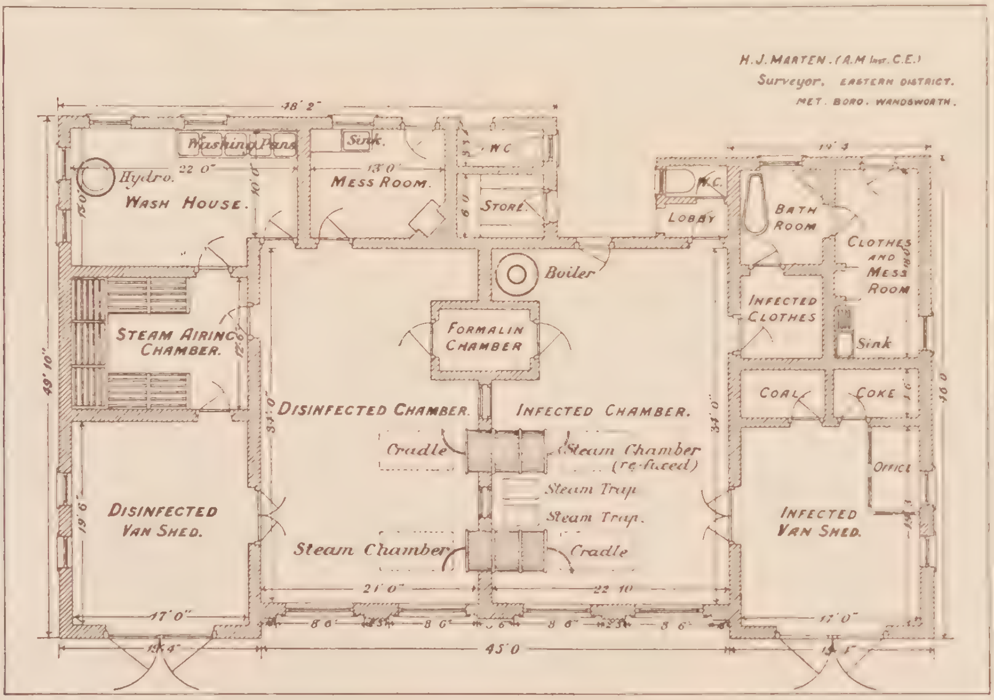


FIG. 1.—Disinfecting Station, Tooting, S.W.

3. The most important equipment in a disinfection-station is the steam-disinfector. Considerable use was made of steam-disinfection before the facts which affect their efficiency were known; and very many stations are equipped with steam-disinfectors which give no certainty of real disinfection, and are probably doing some mischief through the

false confidence which they engender. Complete disinfection of all organisms in practical conditions can be obtained only by the use of saturated steam, free from air and applied at a pressure of 10 to 20 lbs. per square inch for a period which for ordinary objects varies from 15 to 30 minutes. The omission of any of originally in the disinfector must be displaced by or blown out with the steam which enters; that is to say, the steam must be applied as a current until the air in the chamber has been removed. The use of what is sometimes called a "vacuum," but in fact is a partial vacuum only, removes a part of the air. A

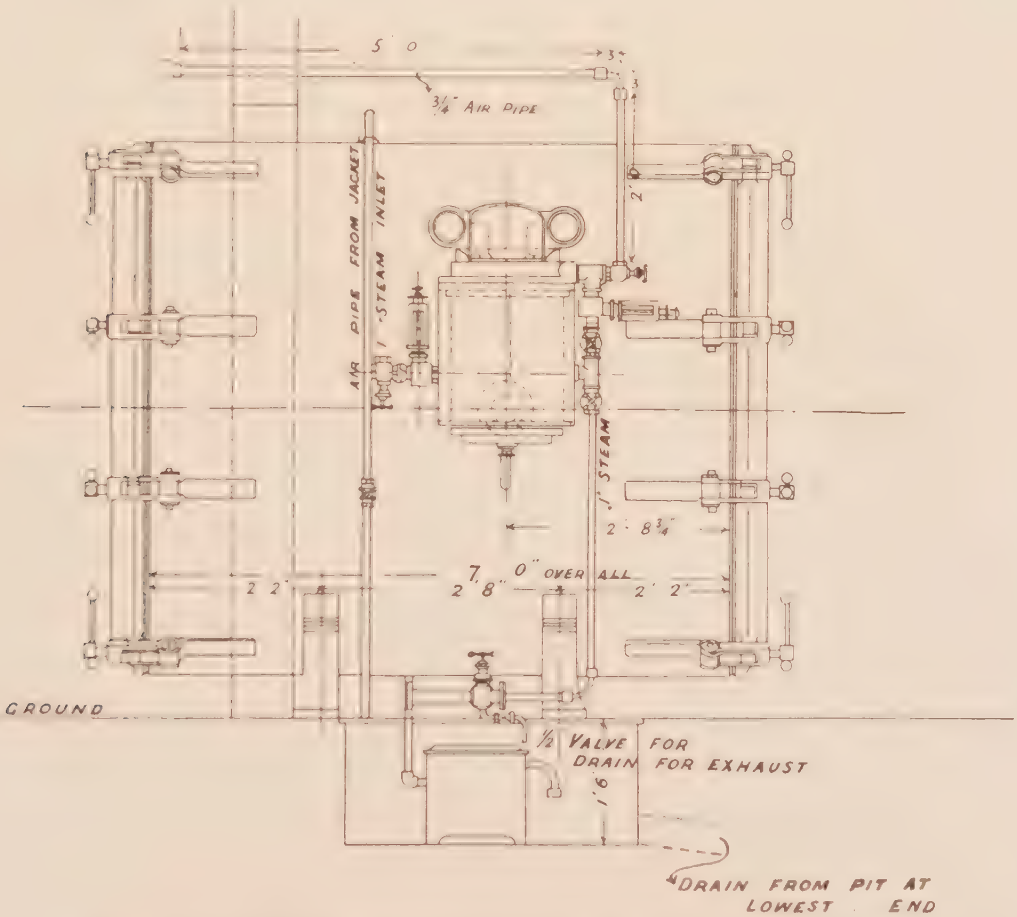


FIG. 2.—Showing Plan of Disinfecting Machine and arrangement of Steam Pipes.

these conditions may at any time cause failure of disinfection. This danger is the more serious because, when failure occurs, it is seldom possible to trace the return case to the real cause; and expense may be incurred through continuance of an epidemic and through precautions against some innocent assumed cause, which might have been spared by correct design of the disinfector.

To obtain steam free from air, the air "good vacuum" of this character corresponds to some 20 in. of mercury, and thus leaves one-third of the air in the disinfector; a mixture much less efficient for disinfection than pure steam. Apart from the air in the disinfector, a certain amount will remain in the pores of the mattresses and other thick objects; this air is removed by periodically blowing off steam from the disinfector after it has been allowed to reach the necessary pressure and

has remained at it for a few minutes. Saturated steam is usually obtained from an ordinary vertical boiler. It should be passed through a separator before being admitted to the disinfector, so as to avoid the admission of pre-formed water, which retards the penetration of heat and the ultimate drying of the objects under treatment. When the boiler in each operation should always be secured independently of the attendant. While involving no sensible addition to the cost of working and not much to the first cost of the plant, the use of this precaution is convenient to the attendant in giving him a record of what he is doing. It is still more convenient to the officer responsible for the station, not only in

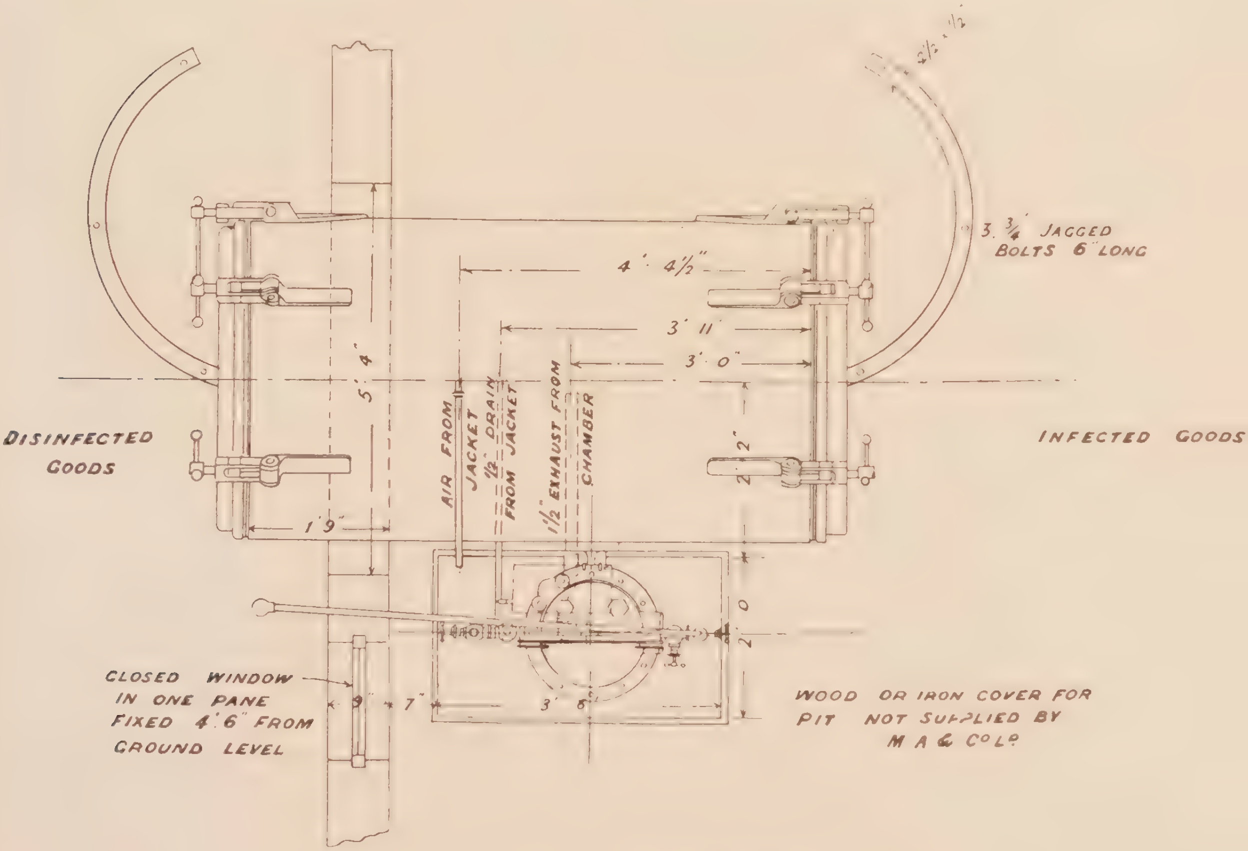


Fig. 3.—Plan of Disinfecting Machine.

forms part of the disinfector, care must be taken to see that the steam is not superheated by excessive transmission of heat from the furnace-gases through the shell of the steam-space. This defect occurs in many self-contained disinfectors, and prevents uniform heating and complete disinfection. It also gives rise to scorching of goods, which subjects the authority to claims for compensation.

The assurance that all the necessary conditions for true disinfection have been attained giving him direct proof that the disinfector has been worked efficiently, but also in enabling him to exhibit this proof to others. The most satisfactory way of obtaining this control is to connect a by-pass from the disinfector to a gauge which, when the steam in the disinfector is free from air, permits the steam in the by-pass to enter a recording pressure-gauge, on which it traces a curve indicating the pressure attained and the period of exposure. When the operation is

interrupted, as, for instance, on blowing off for the ejection of air from the pores of mattresses, the by-pass closes automatically, and the freedom of the steam from air has to be verified again before the steam can pass to the recording gauge and give credit for further disinfection. The apparatus is usually arranged to be worked merely by pushing or pulling a button, and its use involves no skill whatever. In most disinfectors means are provided for drying thick objects, and it is very important that they should be rapid and efficient, so as to avoid scorching and dampness. Immediately on removing the objects from the disinfector they should be thoroughly shaken and hung up or laid out to air, as their relative high temperature enables the film of steam which hangs about them to be detached and the pores to be filled with dry air more readily than after they have cooled.

Where considerable variations are likely to occur in the amount of work to be done at a station, it is possible to economise in steam by installing two disinfectors, of which one serves to do the normal work and the other the excess. In such installations it is usually better to have two sizes of disinfector, say 7 ft. 6 in. by 4 ft. 3 in. diameter and 9 ft. by 6 ft. diameter. An alternative method of getting excess of work out of a disinfector is to have an auxiliary drying closet, which is used to relieve the disinfector for the period ordinarily occupied in drying. With this arrangement the drying closet must be larger than the volume of the disinfector which it relieves, as the transfer of goods from the

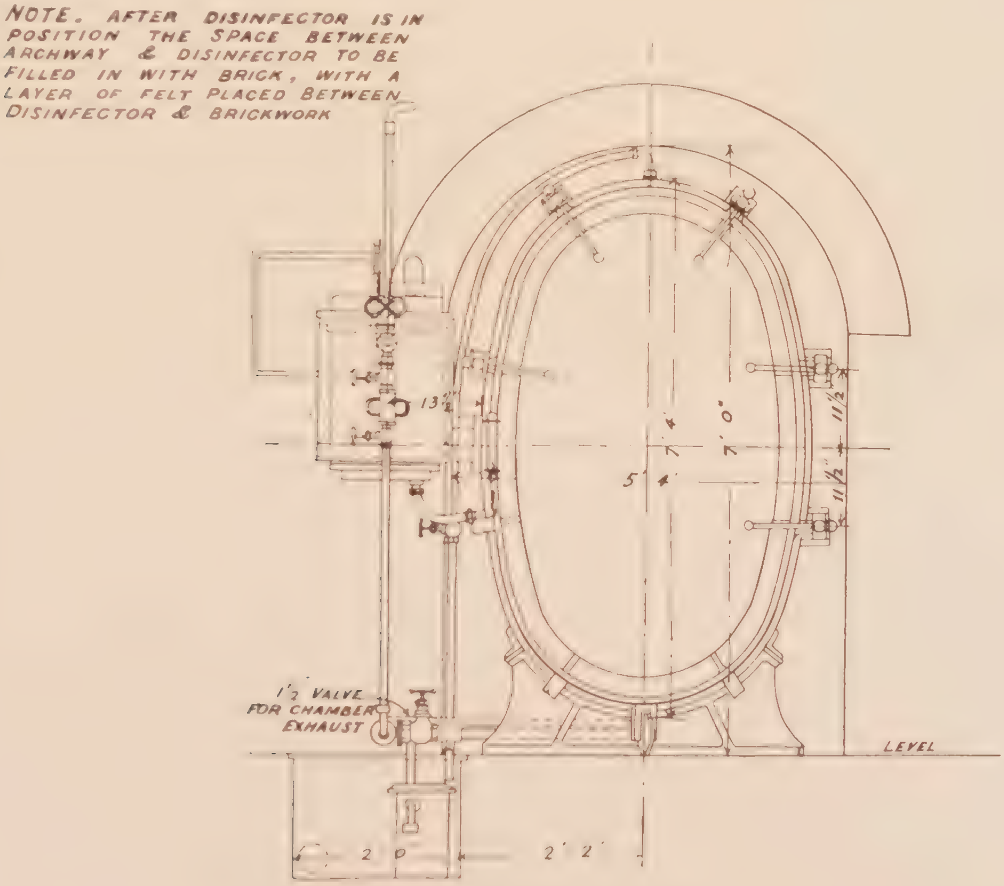


FIG. 4.—Section of Disinfecting Machine.

disinfector to the closet entails a certain amount of condensation and a proportionately longer period of drying. Given such a closet, the work done by a good disinfector may be approximately doubled when it is relieved from the duty of drying. A drying closet may be worked with a fan or by natural ventilation, and is best furnished with "horses" to draw out as in laundry practice. The disinfector should drain into a steam trap, to avoid nuisance and loss from escaping steam. If drying coils are used with steam at a higher pressure, a separate steam-trap will be required. If the exhaust from the disinfector is a nuisance, it may be fitted with a condensing silencer. The disinfector and boiler should be thoroughly well lagged to reduce the loss and inconvenience due to escape of heat. A disinfector should always be warm before goods are put in it for treatment, and they should be removed as soon as the operation is over. Where the funds necessary for a disinfector for absolute disinfection are not available, a low-pressure or a non-pressure disinfector must be used. The design of such a disinfector must be such as to drive the fastest possible current of steam through the disinfecting chamber. Longer time must be allowed both for disinfection and for drying them in disinfectors working at higher temperatures. Such disinfectors are perfectly sufficient for dealing with enteric fever, diphtheria, cholera, and certain other diseases associated with sporeless organisms. There is no evidence that they can be depended on to disinfect from small-pox, scarlet-fever, or measles. Steam for a disinfector may be derived from a neighbouring destructor station. In this and other cases in which steam is brought to the disinfector from a distance the efficiency of drying and, to some extent, of disinfection depends largely on the pipe-run being well designed and the pipes thoroughly lagged.

4. The accessory appliances needed for a disinfection station are: (*a*) convenient racks for airing and stacking disinfected objects. The best airing racks are of steam-heated tinned copper pipes. They are more costly than wood, but take less labour to keep clean, last longer, and are much more rapid in operation. (*b*) A small tank for chemical disinfectant, such as permanganate of potash, so that spots of organic matter may be damped before steam-disinfection, to prevent them from leaving fixed stains. (*c*) A boiling tank for objects too stained with organic matter to make it desirable to go over them with cold disinfectant. Such a tank is preferably made in two parts, one over the other, communicating by two tubes which enter the lower tank at different levels, and arranged so that the liquid contents of the lower tank boil up into the upper tank and there steep the clothes, &c., circulating continuously from lower to upper tank, and ultimately falling back into the lower tank at the end of the operation. This construction ensures the constant exposure of the clothes to boiling water; and by putting washing soda in the lower vessel both the temperature of the boiling water and its cleansing power are raised to a very valuable extent. Where practicable the tank should be arranged like the disinfector through the partition wall, the goods being slid in under water from the infected side and taken out on the disinfected side. (*d*) A spray disinfector for dealing with objects such as furs, leather, &c., which cannot stand steam. (*e*) Hose and flushing apparatus enabling all parts of the station to be flushed down. (*f*) Bath and basins for attendants with hot and cold water. If cleansing of persons is undertaken, two other separate baths, for men and women respectively, should be provided in a room adjacent to the disinfector room, so that the clothes of persons may be disinfected and deverminised while they are in the bath. (*g*) A store for the utensils (spray-disinfectors, brushes, bottles, soap, &c.), served out to the house-disinfectors in their daily rounds. (*h*) An incinerator for burning objects not worth disinfection.

W. D.

Distemper.—A water paint made by mixing refined chalk with water and an

agglutinant such as ordinary size, colour being added when desired. Ordinary whitewash is an example of a distemper. Of late years ordinary distempers are being used less than formerly, their place being taken by washable water paints or distempers. (*See* "PAINTS AND PAINTING.")

Distributors, for Sewage.—An essential feature of the "percolation bed" for the disposal of sewage lies in distributing the liquid uniformly, and at a suitable rate, over the whole of the surface of the bed, so that it may percolate through by dripping slowly from particle to particle of the filtering material and thus become thoroughly exposed to the air and the nitrifying influences of the bed. This object is accomplished in a variety of ways, that most generally adopted being distribution by means of a continuous rain-like shower from revolving "sprinklers" working in a horizontal plane on the Barker's mill principle, or by means of "jets" or nozzles placed in rows of fixed pipes carrying the sewage under a head of from 5 to about 10 ft. In some cases the same object is sought by the employment of distributors travelling on rails and carrying a series of buckets or nozzles arranged to embrace the full width of the bed. At small works distribution has also been affected, with varying degrees of success, by means of balanced trays or tippers, and sheet-iron gutters or troughing. Whatever form of distributor is adopted, it is important that it should distribute the liquid uniformly without interruptions from wind, frost, or other atmospheric conditions, that it should not easily stop through clogging of small holes and that it should be easily and quickly cleaned. It should be self-adjusting to variations of flow, and the bearings and central moving parts through which the sewage is admitted should be of special and appropriate design. The means first adopted for distributing sewage over percolating filters consisted in the use of a fine surface material over which the sewage was flushed and distributed by flooding. The result, however, was not satisfactory as the top layer and coating greatly impeded aëration and led to unevenness of distribution. Trials were also made with both wooden and iron troughs provided with holes and notches placed over the surface of the bed at intervals of 2 or 3 ft., but the difficulties of keeping these level and the notches clear contributed largely to unevenness and cost of distribution insomuch that the system is found almost impracticable except for small installations. A greatly improved iron trough and tipper arrangement has been introduced by W. E. Farrer, of Birmingham. With the object of securing more constant and uniform distribution than is obtained by troughs, a distributor, constructed of a special form of corrugated iron sheets, was introduced by F. Stoddart, of Bristol, and over this the sewage runs from the main carrier into small channels formed by the corrugations. The sheets are punched with numerous holes to allow the sewage to drip through uniformly on to the beds from a great number of small points thus provided. It is necessary, however, that the sheets should be absolutely level and the holes kept clear from obstruction by frequent brushing. At Lichfield, about the year 1898, a system of perforated pipes, working under pressure as suggested by Mr. Garfield, was introduced and has since been working satisfactorily. The "jets" work under a head of 7 ft., and the sewage is discharged in fine sprays by the use of small metal plates placed over each jet upon which the liquid impinges and is thus scattered over a wide area. The whole series of distributing pipes are so arranged that they can be turned through an angle of 45° and the jets thrown first on one side of the tube and then on the other, thus securing a good and even distribution. A somewhat similiar arrangement is in use at Chesterfield, but here the quantity of sewage is varied from time to time by an automatic ejector. The liquid as it impinges on the iron plates over the holes in the distributing pipes is thrown in a circle all around, the radius of which narrows as the head or pressure from

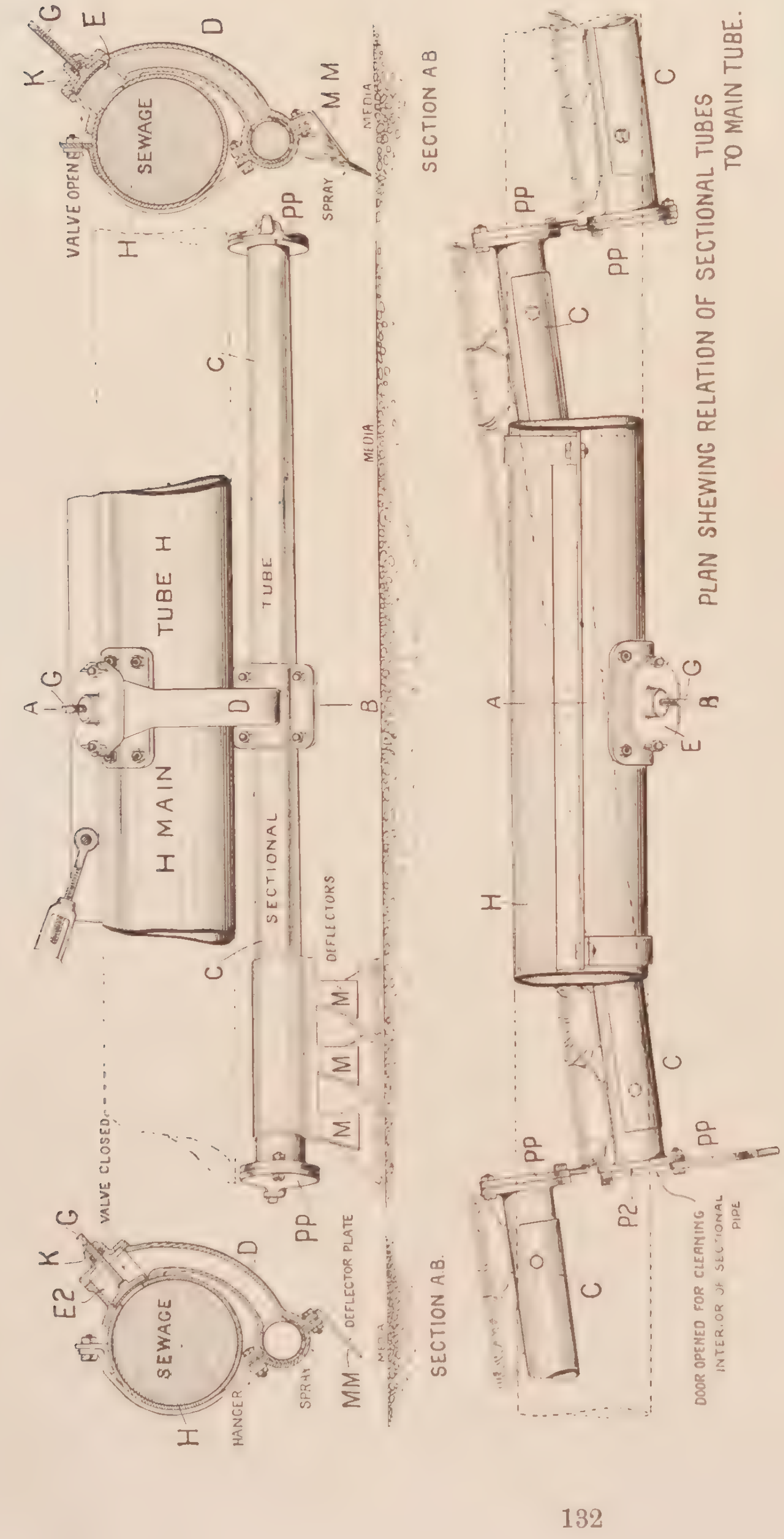


Fig. 11.—Sectional Distributing Tube of Hartley Circular Sewage Distributor.

or mechanical filtration beds for removing the fine suspended matter from the percolating bed effluent, and there are also 17 acres of land available. The sprinkler has only one distributing arm and this is supported by three wheel carriages running on three concentric tracks, one in a small well at the centre, one near the circumference of the bed, and one at an intermediate position. The distributor is supplied by means of a siphon from a stand-pipe at the centre of the filter. The siphons from all the distributors are connected by means of air pipes carried to the engine-room where they connect with a vacuum chamber, and the beds are thus readily controlled by opening and closing the necessary taps or valves in the engine-room for the purpose of starting the siphon feed to each bed as required. The distributors were supplied by the Patent Automatic Sewage Distributors, Ltd., of Westminster.

In another type of rotary distributor for circular beds the rotating arms are fitted as small water wheels, with a number of buckets or troughs around the circumference and extending throughout the length of the arm. The apparatus

is supplied with sewage, by means of a feed pipe from the centre of the filter and rotates upon circular rail tracks at the centre and periphery of the filter. The "Fiddian" distributors for circular filters as introduced by Birch, Killon, & Co., engineers, Manchester, are of this type, and one is installed at Fazakerley for the Liverpool Corporation.

Fig. 12.—Sewage Distribution at Worcester: Self-propelled Candy-Caink Sprinkler.

The propelling power for the class of distributor shown in Fig. 13 is also developed on the principle of the water wheel, but instead of taking a circular path the apparatus travels backwards and forwards over filters of a rectangular shape, thus securing great economy of space as compared to the circular form of bed.

The most effective method of applying sewage to bacteria beds is in the form of a small jet or fine spray, and in selecting a distributor it should not be one of the type which dashes the sewage on to the bed in bucketfuls so as to cause rapid downward flushes through the bed. The disadvantageous effect of this is minimised by using a fine top layer over the surface of the bed, but this will usually need cleaning and aërating from time to time. The water-wheel type of distributor is less satisfactory than the rotary and fixed spray type in this respect, whilst the initial cost and maintenance is also heavy. Siphonic feeds to distributors are oftentimes troublesome through risk of "air-locking," and the introduction of mechanical joints between the fixed and moving parts of such apparatus, as by means of an ordinary stuffing-box and gland, causes much friction and resistance to the rotary movement of the distributor. Efforts have also been made to

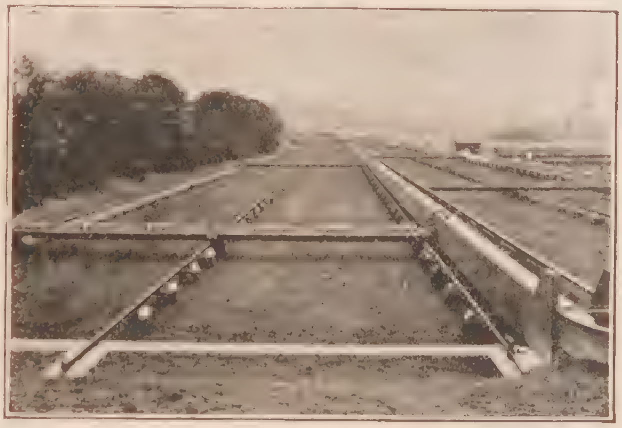


Fig. 13.—Ham, Baker's Travelling Distributors.

develop power for driving distributors by passing the sewage through a turbine interposed between the central supply pipe and the distributing arms, but the advantage would appear to lie with the "Barker's mill" principle inasmuch as the reaction of a jet issuing from the distributor arm at a distance from the centre of rotation must be more effective than a similar jet escaping close to the centre and with a very short leverage through which to act.

The influence of the wind has an important effect upon the working of moving distributors propelled by a small head only of sewage liquor, and in some cases they are frequently brought to a standstill, thus permitting the liquid to pour upon the filter at one spot and stream through the bed to the effluent channel in an untreated condition. The effects of continued severe frost and snow occasionally derange the working of distributors, but where they can be kept in full use throughout the 24 hours the warmth of the sewage itself is generally sufficient to prevent freezing. If the distributor is not in full use it is best drained off dry to avoid bursting of pipes, &c., should freezing of the water contained therein occur. The distribution of the sewage by all existing forms of distributors may at times be far from perfect, especially where only a limited amount of attention is given, so that it becomes important to have sufficient depth of bed to distribute and equalise such imperfections. W. H. M.

Dortmund Settling Tank.—This is a circular conical-bottomed precipitating tank first tried at Dortmund, in Germany, by Carl Kinebühler, and afterwards at the Chicago Exhibition. The sewage, after preliminary settling in an ordinary horizontal tank, passes down a vertical central downpipe about 3 ft. 6 in. in diameter, to a depth of some 30 ft., where the sludge settles in the conical shaped bottom. Radial arms are provided at the upper end of the conical portion of the bottom of the tank for the purpose of distributing the sewage evenly throughout. As it consolidates the sludge in the apex of the cone is pumped out by a 6 in. suction pipe. This type of tank, like others which are offshoots of the same original idea, embodies a good principle in the continuous upward flow of the sewage with a downward movement of the sludge, but in practical working has not given the satisfaction first contemplated by many, inasmuch as the sludge does not always gravitate into the cone but floats or settles on the sides, where it decomposes. Colonies of bacteria also form, and these together with the putrid sludge pass off with the effluent. Matters may, however, be improved by removing the sludge daily, by adopting a revolving scraper for cleansing the internal surfaces of the tank walls, and by having the tanks in duplicate.

Dosing Tank.—The name "dosing tank" is applied to a small chamber placed between the precipitating or settling tanks and the contact or percolating beds for the purpose of accumulating a sufficient volume of liquid for distribution on to the filters in cases where the flow of sewage is small during certain periods of the 24 hours. Where a rotary distributor is used, in the case of a small works, the flow may fall during the night to such an extent that the distributor will not revolve, and in these circumstances the sewage is stored in a "dosing tank" from which it is discharged in bulk, by means of a siphon or other suitable contrivance, on to the filter beds, which are thus afforded intermittent periods of rest.

Drainage—Cast-iron.—Cast-iron drainage differs from ordinary house drainage only as regards the materials of which the underground drains are constructed. It has many advantages over stoneware drainage, whereas only one drawback may fairly be urged against it, and that is the question of cost, which is about 30 % more than that of stone-ware; but having regard to the security obtained by the use of iron, it is, doubtless, the most economical material in the long run. Apart from having a longer life than stone-ware drains, in itself a great advantage, cast-iron

drains are also superior in other respects. In the first place the pipes are made in longer lengths, there being a joint every 9 ft. in an iron drain as against every 2 ft. in a stoneware drain. As it is generally accepted that the fewer joints there are in a drain, the

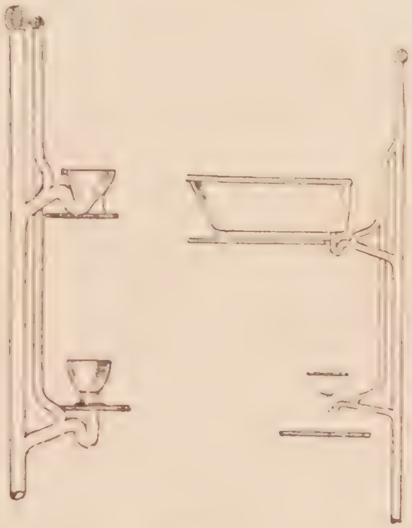


FIG. 1.

fewer chances there are for imperfections, the advantages of iron over stoneware would be in the ratio of 4½ to 1. It follows from this also that the time occupied in laying a given length in each material, and consequently the cost of labour, is distinctly in favour of the iron drain. Secondly, the joints of iron drains can be made in all weathers and in all soils, which is a great consideration in the case of drains constructed during periods of frost or rain or in water-logged ground—conditions which would seriously interfere with the making of stoneware pipe joints. In the third place, there is a greater likelihood of a stoneware drain giving way, owing to pressure, settlement of the ground, or to vibration, such as that produced by an underground railway or by heavy vehicular traffic, by reason not only of the increased number of joints and correspondingly increased number of points of possible rupture, but also because of the more brittle nature of the materials of which both the pipes and the joints are made. In the fourth place, iron drains may be laid in a variety of ways which would be impracticable in the case of stoneware drains. They may be fixed openly against walls or suspended from ceilings (see Fig. 1) where the lowest floor of the building is below the level of the public sewer, or they may be laid, subject to proper fixing, above the floor of a basement or in a culvert. They will be as safe there as if laid underground, and possess the advantage that every portion will be easily accessible and visible. On iron piping the manholes may be made on the piping itself, as shown in Fig. 2. This will obviate the necessity for constructing air and water-tight brick manholes. A further advantage of cast-iron over stoneware drains is that the former do not require continuous concrete foundations except in cases where the ground is particularly bad. In most cases it will be sufficient to provide a concrete pier about 1 ft. square and from 6 in. to 12 in. deep according to the nature of the ground under each socket. All cast-iron pipes used in drainage work should be made of good tough grey iron of the second melting run from the cupola. The pipes should be cast with sockets downward and with an extra head of at least 1 ft. of metal. All pipes above 4 in. in diameter should be inclined

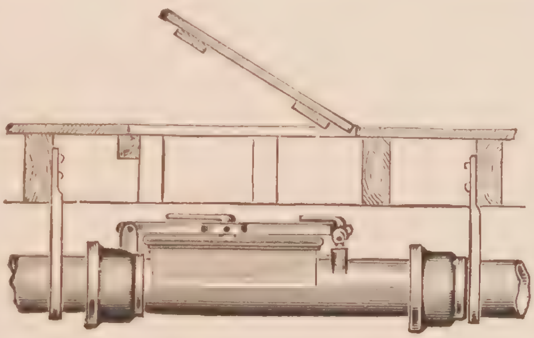


FIG. 2.—Access Pipe or Hatch Box on Iron Drain.

at an angle of 45°. The pipes should be straight, true in section, even in thickness of metal, perfectly smooth inside, and free from air and sand holes and other defects. The sockets must be strong, deep, and sufficie[ntly] wide all round to leave room for caulki[ng]

the joint; whilst the spigots of the pipes must be provided with a bead on the end. This bead causes the spigot of one pipe to lie in the socket of the other in such a way that the pipes are concentric when joined. The bead will also ensure an equal annular space all round the inside of the socket, and help to keep the lead used in making the joint from running into the interior of the pipes. The walls of the sockets should not be less than ¼ in. thicker than the walls of the pipes, whilst the internal diameter of the sockets should be from ½ in. to ¾ in. larger than the external diameter of the pipes, so as to leave a sufficiently large annular space all round the pipes for the lead joints. The pipes must be capable of withstanding a pressure of 200 ft. head of water, and must be coated, both inside and out, by some anti-corrosive solution, such as Dr. Angus Smith's composition, to prevent deterioration through oxidation. For the proportions and weights of cast-iron pipes see article "Cast-iron Pipes."

The joints of iron drains should be made with molten lead well caulked whilst cooling.

G. J. G. J.

Drainage, House.—The objects to be attained in carrying out a perfect system of house drainage are:—1. The disconnection of the drains from the public sewer or other outfall. 2. The disconnection of the rain and waste-water pipes from the house drains. 3. The thorough ventilation of the whole drainage system. 4. The entire and immediate removal of all matter discharged into the drains. 5. The provision of means of access for inspection, testing, and cleansing of the drains. 6. The construction of the entire system in such a manner and of such materials as shall preclude the possibility of leakage of either liquids or gases.

1. Of these requirements the first is attained by breaking direct aërial communication be-tween the drain and sewage outfall by the sertion of a ventilated disconnecting trap article "Disconnecting Traps") at the end of the drains. For convenience of cleansing, &c., this trap is best fixed in a manhole; the drain or drains discharging into it terminating in an open channel running into the trap. This disconnection is desirable for the protection of the house drains against infection from sewers, be that infection merely one of fouled air, of dangerous gases, or of germs of disease.

2. Secondary disconnection is effected by breaking the direct communication between waste-water and rain-water pipes and the drains by the use of gully traps. These are placed at the heads or inlets of all drains that do not take water closets or soil pipes, and serve to shut out from the waste and rain-water pipes, all vitiated air generated in the house drains themselves. The pipes may be discharged over or beneath the gratings of the gullies, but must in all cases have their open ends above the level of the water standing in the traps, which latter must be fixed in the open air. It occasionally happens that a waste pipe or rain-water pipe must of necessity pass down in the interior of the house. In such a case it should be continued below ground in a horizontal position (at a proper fall) to the exterior, and there discharged over a gully. Should this arrangement prove impracticable, the gully may be fixed within the building, but as there is a chance of its water-seal evaporating and consequently of foul air being liberated, the gully must be hermetically sealed at the ground level and the waste pipe provided with an air inlet opening terminating in the open air.

3. The third object named as being necessary to ensure a sanitary system of drainage is ventilation. This is essential in the first place to secure proper disconnection, and secondly, for the oxygenation of the interior of the drains or pipes, and for the dissemination of such gaseous products as may be generated in the drains or waste pipes. For proper ventilation there should be both inlets for fresh air and outlets for vitiated air. Moreover, if ventilation is to be complete, the inlets and outlets must be, as far as practicable, at the extreme opposite ends of the

drains or pipes to be ventilated. It is, moreover, necessary that the inlets and outlets should be at appreciably different levels, since there will otherwise be a tendency to equilibrium due to the collection of the heavier gases, such as carbonic acid gas, at the lowest points of the drains, &c. Soil pipes, having in any case to be carried up above the roof of the building upon which they are fixed, provide convenient and inexpensive up-cast ventilation shafts, and are, therefore, usually made use of for the purpose. If it is possible to so arrange the soil pipes that they may ventilate the whole drainage system, no other up-cast shafts will be necessary. Taking the case of a small house, or of an ordinary town house, for instance, if the soil pipe is at the head of the drain, through-ventilation is attained by the provision of an air-inlet at the opposite end of the system. In cases where the soil pipe is centrally placed a second up-cast shaft will be necessary at the head of the drain, or alternatively an air-inlet at each extremity of the system. This latter method is not permitted by the by-laws of many towns. In other cases, where one or more long branch drains exist, the head of each must be provided with a ventilation shaft. This arrangement, however, involves the splitting up of the air-current drawn through the inlet, and tends to produce inefficient ventilation as the air usually travels through the path of least resistance, and possibly would only occasionally reach some of the outlet shafts under favourable circumstances. It is desirable, therefore, in an extensive drainage scheme, to subdivide the system by judicious trapping and to provide a separate air-inlet to each section. Short branch drains require no special provision for ventilation, as the flow through them will as a rule suffice to displace the air contained therein and so bring it under the influence of the air-currents in the main drains. Ventilation shafts, other than soil pipes, should not be less than 4 in. in diameter, and should preferably be constructed of lead piping. Cast-iron pipes, although frequently used, being cheaper, are not desirable, as they are acted upon by gases occasionally present in drains and also rapidly deteriorate by rusting. Soil pipes should not be less than 3½ in. in diameter, nor more than 4 in., and may be made of drawn lead piping of not less than 8 lbs. to the superficial foot, or of heavy cast-iron piping. In the case of soil pipes washed by sewage, the iron is protected from deterioration by the slimy film which soon forms on their interior. That portion of the pipe which lies above the highest closet and receives no sewage should, however, be of lead in all cases. All outlet ventilation pipes should be carried up full bore, above the roof, and terminated well out of the way of windows and chimneys. Their openings should be protected against blockage by domical copper wire guards. Cowls are not necessary, nor advisable, as they frequently only serve as shelters for birds' nests. Inlet ventilation pipes should be arranged to have their openings in positions where they are not liable to cause annoyance should there be a back-draught from the drains. They may then be simply protected by open gratings. The mica flap valves frequently made use of for shutting off occasional back currents from the drains are not desirable fittings, as they are very liable to get out of order, and, either to leave the inlets open at all times or to permanently close them. The proper ventilation of waste pipes, by which is understood the discharge pipes of sinks, baths, and lavatories, is important, not only to prevent them from becoming foul, but also because the traps of fittings discharging into them are liable to lose their "seal," should the waste pipes be unventilated (*see* "SIPHONAGE"). The not unusual practice of constructing waste pipes with hopper heads, into which the discharges of various fittings are collected, is not desirable, because if ventilated near windows considerable nuisance arises. The pipes should be continued up to above the eaves of the roof for ventilation in a similar manner as soil pipes, and the branches from the fittings connected to the main stack pi

This, of course, is only necessary in the case of waste pipes from fittings fixed upon the upper floors. Short waste pipes from fittings on the lowest floor are sufficiently well ventilated by the provision of "puff" pipes carried to the exterior. Where a number of fittings discharge into a stack pipe common to all, the trap of each fitting, other than the highest one on the stack, must be further ventilated by an anti-siphonage pipe, which may be branched into a main ventilation pipe taking them all and carried up to the eaves independently (as shown in the illustration under the article "SIPHONAGE"), or branched into the ventilation pipe from the waste pipe above the level of the highest fitting on the stack. This applies also to the traps of water-closets where a number of these fittings discharge into one soil pipe.

4. The immediate removal of the sewage discharged into the drains is dependent upon proper gradients, suitable dimensions, and efficient flushing arrangements. In size, the drains should be as small as practicable, as this will tend to cleanliness and a rapid discharge. Thus a flow of sewage which will cause a 4-in. drain to run full and to be self-cleansing on account of the thorough flush which it receives, will not even half fill a 6-in. drain; while a 9-in. drain would only run about one-quarter full. As the mean velocity of sewage flowing through a drain varies directly (up to a certain point), as the depth of the flow of sewage, the drain in which the sewage flows deepest (*i.e.*, the smallest drain) will have the greatest scouring and cleansing flow. Moreover, in an unnecessarily large drain, which is never properly flushed, there is room for splashing and for the deposit of sewage matter, a condition of things which is opposed to true sanitation. In designing a system of drainage the probable flow of sewage should be carefully calculated, as also should the possible amount of rain-water to be removed. Should a small drain, say a 4-in., be found insufficient to take the whole flow, it will be desirable to provide a small drain for the sewage proper and a certain amount of the rainfall, and to lay a second drain for the removal of the remaining rain-water. This course is preferable to the laying of a large drain which would only be thoroughly cleansed during periods of heavy rains. No less important than their sizes are the gradients of the drains. It should be borne in mind that even the smallest drain (which in practice should not be less than 4 in. in diameter) will only run full, or nearly so, under exceptional circumstances. During dry weather, for instance, the flow through the drains will consist merely of excrementitious matter and waste water, the bulk of which will be delivered into the drains spasmodically through waste pipes considerably smaller than the drains. It is, therefore, necessary in laying a drain not only to make use of small piping, but also to lay it at gradients which will provide it with a self-cleansing flow, that is, with a flow sufficiently deep to float fæcal matter to the outlet. In an excessively flat drain the flow of sewage will be so sluggish as to permit the deposit of the heavier portions of the sewage. In an excessively steep drain, on the other hand, the depth of the flow may be so small as to be insufficient to float the larger particles of sewage to the outlet of the drain. Both extremes must, therefore, be avoided. The most suitable falls for drains are those which will impart to the sewage a velocity of 3 ft. per second when the drain is flowing quarter full, or, what is equivalent thereto, a velocity of 4 to 5 ft. per second when flowing full or half full. These falls are roughly:—

For a 4 in. drain	. .	1 in 40.
,, 5 in. ,,	. .	1 ,, 50.
,, 6 in. ,,	. .	1 ,, 60.
,, 9 in. ,,	. .	1 ,, 90.

These gradients should, as far as possible, be adhered to in all cases. Where the fall available is not sufficient to give these gradients throughout the system, the branches should be

so laid and the main drain given a somewhat smaller rate of fall and provided with means of flushing, rather than sacrifice the self-cleansing gradients of the branches, which cannot be coveniently flushed individually. As already stated it is only occasionally that any considerable volume of sewage is discharged through a house-drain at one time. During the periods of minimum flow, therefore, even the best of drains will be far from self-cleansing, and it is therefore desirable that all drains should be periodically and efficiently flushed. Automatic flushing is of the greatest assistance, not only in keeping a drain free from deposit, but also for the removal of grease, and should be made use of whenever possible. The great point in drain flushing is to discharge the available water periodically, automatically, and in suitable quantities, at a rate of, say, from 2 to 4 gallons per second. For this purpose appropriate apparatus (*see* "FLUSHING TANKS") are necessary in order that the water may be collected and retained until the desired quantity has accumulated, and then suddenly discharged into the drains. Under such a system on the one hand, the merest dribble of water may be made use of, while on the other 40 or 50 gallons of water may be made more efficient than 1,000 gallons discharged in a small continuous stream. Flushing tanks should be fixed at the head of the main drain where the drainage system is a small one, and at the head of each of the most important branch drains where the system is extensive. If possible, it should be arranged that one tank discharges into the drain taking the flow from the scullery sink, as this is frequently highly charged with grease. The discharge pipes of the tanks may be connected to the drains through back inlets or ordinary gullies, or they may be attached to the arms of flushing rim gullies, that is gullies provided with flushing rims and made specially for the purpose. The capacities of the tanks must necessarily depend upon the diameters, lengths, and gradients of the drains upon which they are provided. Broadly speaking it will be found that the following volumes of water will give satisfactory results:—

For a 4 in. drain .	. 30 to 40 gallons.
,, ,, 5 ,, ,, .	. 40 ,, 60 ,,
,, ,, 6 ,, ,, .	. 60 ,, 100 ,,

5. As a broad principle, every pipe and connection comprised by the drainage system should be made accessible throughout, for the purpose of enabling stoppages to be located and removed without loss of time and without damage to the component parts of the system. It permits also of the inspection, cleansing and testing of the drainage system, enables leakages to be located and rectified without unnecessary laying bare of drains, and therefore brings all that would otherwise be out of sight and out of reach under perfect control. In vertical piping such as soil pipes, waste pipes, and pipes above ground generally, means of access are provided in the case of iron pipes by the use of suitable access pipes made for the purpose. They consist of pipes, straight or bent, fitted with removable lids which are capable of being closed air-tightly. (*See* "ACCESS PIPE.") In lead pipes access is provided for by the insertion on the pipes of screwed brass caps and sockets. These openings into the pipes must be suitably placed so that the fullest advantage may be derived from them both for the removal of accumulations, where such are liable to take place, and for the insertion of a cane or brush for cleaning purposes whenever that should become necessary. In underground piping, that is in the drains proper, access is provided by means of manholes which should be placed at all important changes of direction, and also on straight lengths of drain wherever these are considerable. All branch drains should be arranged to join the main drains in these manholes, and the drains to or from them laid in perfectly straight lines from point to point. Manholes should be constructed of brickwork in cement upon proper cement concrete foundations, and should be ma perfectly water-tight up to the gr

level. This is arrived at by rendering the surfaces of the manholes with cement or by lining them with slabs of plate glass. Manholes constructed of glazed bricks are not desirable, because, although capable of being made water-tight, the joints of the brickwork favour the accumulation of dirt. The manholes, which should be situated in the open, must be covered at the ground level with air-tight iron covers and frames. Should a manhole of necessity have to be placed within a building, a double cover, capable of sealing itself by the condensation arising from the drains, must be provided, or other means adopted to ensure that the covers shall be permanently air-tight. Through these manholes all drains should pass in the form of open channels shaped out of concrete and rendered in cement, or properly shaped glazed stoneware channels set in cement. It is desirable that the branch channels should be at a slightly higher level than the main channel into which they deliver. The branch channels should, further, invariably discharge in the direction of the outlet of the manhole and should be so placed that the discharge of one does not enter any of the channels on the opposite side of the manhole. The most convenient proportions for ordinary manholes are :—

For manholes 1 ft. 6 in. or less in depth—2 ft. by 2 ft.
,, ,, between 1 ft. 6 in. and 2 ft. 6 in. in depth—2 ft. 6 in. by 2 ft.
,, ,, above 2 ft. 6 in. in depth—3 ft. 6 in. by 2 ft. 6 in.

When over 7 ft. 6 in. in depth the upper portion of the manhole may be contracted in size by constructing an arch at a height of 5 ft. above the invert of the drain; a shaft 2 ft. by 2 ft. in the interior being carried up to the level of the ground. The construction of an ordinary manhole is shown on page 77.

6. Construction. — Upon this is dependent, more than upon anything else, the health and well-being of the inmates of the house in connection with which the drainage system has been provided. The entire system must be water-tight to prevent the pollution by sewage of the subsoil and foundations, and in many cases also the pollution of the water-supply to the house or other buildings in the vicinity. It must also be air-tight to preclude the possibility of polluting the air. The materials made use of in drainage construction are cast-iron and stoneware. For the former, which has many advantages, see article "Drainage, Cast-Iron." In the case of stoneware pipes, only those of best quality should be made use of. Earthenware or fireclay pipes must be avoided entirely, as they are usually absorbent and are not as tenacious and strong as stoneware piping. Nor are they, as a rule, burnt at a sufficiently high temperature to become vitrified. The stoneware pipes used should be salt-glazed, highly vitrified, perfectly smooth inside, straight, true in section, even in thickness, free from sandholes, cracks, and other defects, and should be provided with strong deep sockets so as to allow of proper joints being made (*see* "Stoneware Pipe Joints"). They should be tested to a pressure of from 20 ft. to 25 ft. head of water. Stoneware pipe drains should in all cases be laid upon a continuous cement concrete bed at least 6 in. thick, and in width sufficient to project on each side of the drain a distance at least equal to the external diameter of the drain. After being tested and found perfectly water-tight, concrete should be filled in on each side of the drain so as to preclude the possibility of lateral movement. Where a stoneware drain passes under buildings or roads or in other similar positions, it should be entirely surrounded by concrete to a thickness of at least 6 in. In each case where the drain passes under a wall a relieving arch should be built over it so that there may be no pressure on the drain. Soil-pipes may be constructed of iron or of lead. In the case of the former the piping should be of at least "medium" strength (*see* "Pipes, Weights and Dimensions of Cast-Iron") and

the joints made with molten lead well caulked. Lead piping should be hydraulic drawn and at least 8 lbs. weight to the superficial foot. Where the pipe has unavoidably to be fixed inside a building, piping of 10 lbs. strength should be made use of. In either case the joints should invariably be of "wiped" lead. Ventilation pipes should, as already stated, always be constructed of lead. Hydraulic drawn lead piping is also the material to be used for all waste pipes, and the joints in this case should also be of "wiped" solder, except where the pipes are of some length and intended to take hot water. Under these circumstances "expansion joints" are permissible in order to allow free movement to the pipes when under the influence of expansion and contraction, which would otherwise soon cause them to break. Rain-water pipes should be of galvanized iron—the ordinary painted rain-water pipe being liable to choke from internal rust. The joints of these pipes should be made with red lead putty. On completion of the drainage system, each and every component part should be subjected to thorough tests, as to which see article "DRAIN-TESTING." It is also desirable that all drainage systems should be tested periodically, so that defects may be discovered and remedied before they reach a serious stage. (*See* "PLUMBING.")

G. J. G. J.

Dry Earth System.—(*See* "EARTH-CLOSETS.")

"Dry-weather flow" of Sewage.—This phrase means the ordinary daily average quantity of true sewage from any given population, free from augmentation by rainfall and subsoil soakage. The quantity should therefore approximate closely to the amount of the water-supply to the same population, and, in a well sewered district, commonly amounts to from 25 to 30 gallons per head of the population, but "trade wastes" and special local conditions may alter this amount in certain cases.

Ducat's Filter.—This is an aërating filter for sewage treatment constructed with external walls of 3 in. drain pipes, laid with the outer ends 3 in. higher than the inner to prevent sewage leaking outwards. Aërating layers of drain pipes are placed at intervals throughout the depth of the filtering material, which latter consists of $\frac{1}{4}$ in. to $\frac{1}{2}$ in. vitrified clinker. The object aimed at is that air should continually pass laterally through the filter with a view of keeping the same regularly at work without intermission. Another feature is that crude sewage is claimed to be dealt with, but experience teaches that under nearly all circumstances some form of preliminary preparation such as screening and settlement of the raw sewage is needed. The direct oxidation of the sewage by currents of air produces considerable cooling; the system therefore requires to be supplemented by hot-water pipes fed by a boiler situate in a heating chamber adjoining. The Ducat system has been experimented with at Leeds, Market Drayton, Hendon, Sutton, and also at the Tattingstone Workhouse, near Ipswich.

Dundrum Settling Tanks.—Mr. Kaye Perry has used tanks to which this name is applied. The tanks are three in number each 7 ft. square by 16 ft. deep, and containing 5,000 gallons of sewage each. The liquid enters near the bottom to each tank in succession, and by the upward flow principle of the Dortmund and other tanks the heavier suspended matters are left behind.

Dust Bins.—Receptacles provided in connection with dwellings for the collection of ashes and other house refuse. These bins should only be used for dry refuse; cabbage leaves, food scraps, paper and similar material liable to decomposition being better disposed of by burning, in which householders should be encouraged. Dust bins frequently consist

of a brick or wooden pit from which the refuse is shovelled out when about to be removed. This involves much dust and nuisance and must be considered insanitary. Better bins are those generally known as "sanitary," which are made of galvanized iron and are provided with a light-fitting lid to exclude rain, as moisture favours decomposition. These bins may be bodily removed for emptying. Preference should be given to those that are round in shape or have rounded corners, as being more readily cleaned. Another form of sanitary bin, much used in the North of England, is one made of metal and hinged in an aperture in a boundary wall in such a way that ashes may be thrown in from the house side of the wall, while the emptying may take place from a passage at the back of the wall by simply tipping over the bin.

Dust Prevention.—Surfacing Roads—Oiled Roads—Dust Palliatives—Apparatus.—The dust problem is a very ancient one, but has only assumed an acute form since the advent of motor traffic. Dust has a deprecating effect upon everything with which it comes in contact, and is a source of great danger to the public health. It not only predisposes to diseases of the lungs, but as a carrier of disease germs is a greater source of danger than mud. To permanently cure the evil would involve greater expense than our local bodies are prepared to involve themselves in. Moreover the vast number of roads which have been formed of macadam only allow of certain palliative measures being adopted. Many engineers suggest a system of roads in duplicate, one for heavy and the other for light traffic, each road surface being made of materials suitable to withstand the strain set up by passing vehicles. This system is, however, prohibitive on the ground of its great expense.

Before treating of palliatives for existing surfaces, we will deal with systems that have been generally adopted for the prevention of dust in making new roads.

Many systems have been employed, among them being wood-paving, tarred macadam, and many patent systems of binders, asphalte, &c.

In every case success largely depends on the foundation of the road, and the reader is referred to the article on "ROADS, STREETS, AND PAVEMENTS" for further consideration of this point. It will be well to point out that only the best materials should be used and the work carried out in the best possible manner.

SYSTEMS OF SURFACING ROADS.—WOOD-PAVING.—This has undoubtedly decreased the dust in main thoroughfares, though much still arises from horse droppings, &c., but if properly ordered as pointed out in the article on "STREET CLEANSING," part of the dust may be speedily removed.

TAR MACADAM.—This method of surfacing roads for dust prevention has been largely adopted with varying results. The materials used are generally limestone or ironstone slag, the latter being stronger than limestone. Care must be exercised over the tar, as upon it depends very largely the success of the surface. In hot weather owing to bad tar or unsuitable stone being used, or defective mixing of the materials, the surface becomes sticky and dangerous. There is little doubt that the best way of drying the stone is by placing it in specially heated ovens, the stone being turned over at intervals to ensure it being thoroughly dried and heated. The tar should in all cases be boiled, and if it is of poor quality a little pitch will improve it. The mixing of the tar and the stone requires very careful attention. Engineers have different methods of mixing, for instance: (1) Cold stone and cold tar. (2) Cold stone and hot tar. (3) Hot stone and hot tar.

After the foundation of the carriage-way has been thoroughly rolled and consolidated, the tar macadam may be put on in one or two layers. The usual depth is about 4 in., consisting mostly of two layers. The bottom layer is about 2½ in. in depth and consists of stone

2 in. to $2\frac{1}{2}$ in. gauge, well rolled; the top coat is about $1\frac{1}{2}$ in. in depth, and consists of stone $\frac{3}{4}$ in. to 1 in. gauge. This is then thoroughly rolled and covered with fine shingle.

Sealed Roads.—These are roads which are surfaced with "binders" such as "Tarvia." In such instances not only has dust been reduced to a minimum, but the cost of cleansing has also been reduced. The system of binding with "Tarvia," as suggested by the manufacturers. is as follows:—The road surface is levelled and covered with a mixture of Tarvia and chippings about $\frac{3}{4}$ in. in thickness, 1 cu. yd. covering about 36 superficial yards. On the top of this layer, a coating of 2 in. roadstone is laid, and in such a manner that 1 ton covers 11 or 12 superficial yards. The whole is then lightly rolled, the effect of which is to force the binder up into the top surface thus filling in all the interstices and providing thereby a waterproof surface. The operation is completed by a top sealing with hot Tarvia. Dry chippings are then spread on the surface and the whole well rolled. A system that has been adopted in Penzance is as follows:—After the old macadam has been scarified and carted away, the surface is covered with a mixture of dehydrated gas tar and refined rock pitch, in the proportion of 8 lbs. of pitch to a barrel of tar. This mixture is poured over the surface in a boiling condition and sprinkled with lias lime. This is then covered with a layer of tar concrete about $1\frac{1}{2}$ to 2 in. in thickness; this also being sprinkled with lias lime, and before rolling covered with macadam to a depth of 3 to 4 in. The whole is then rapidly rolled, to adjust the layers, and afterwards slowly rolled and lightly watered. The effect of this method is to force the fine tar concrete into the top surface covering, thereby filling the interstices and binding the surfaces together. The road surface has stood well and reduced the amount of dust considerably. Another method adopted at Penzance for coating the surface of gradients, with due regard to the dust evil, was the use of a preparation of distilled tar, rock pitch, and lias lime, under the coating of macadam. The surface being thus rendered impervious to wet, and, while retaining its rigidity, afforded a good foothold for horses. Before calling attention to some of the dust palliatives and machines on the market, there are one or two methods

Fig. 1.—Single Sealed Road.

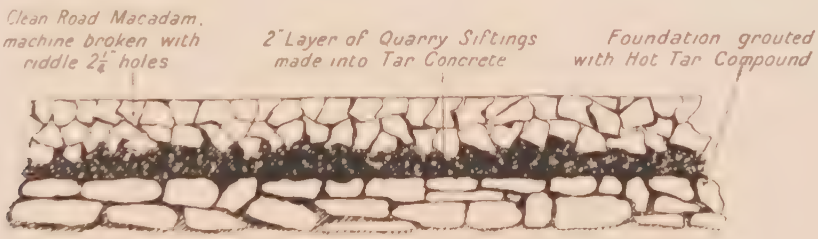


Fig. 2.—Double Sealed Road.

of dressing the finished surface of the roadway to reduce the amount of dust. The materials used form a tar cement and in some cases consist of tar, pitch, and lias lime. The material should be applied to the road surface in a hot condition, and when laid should be sprinkled with fine stone chippings about $\frac{1}{8}$th of an inch, and the whole well rolled. It will be found that this material forms a cushion to the road surface, and reduces wear and tear. Another method which has given excellent results and is inexpensive is as follows:—The road surface should be thoroughly brushed and kept dry to receive the material. The mixture is made of sand, chippings and shell, added to which is a quantity of tar. The whole is then mixed to a mastic state, and then sprinkled over the road surface to a depth varying from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. The surface is then sprinkled with shell and rolled with a hand roller. The cost of this material laid is about $2\frac{1}{2}d.$ per superficial yard.

Dust palliatives still occupy an important position in connection with the problem of prevention of dust, as many of our roads are of macadam, and the expense involved in removing the top surface and substituting one that will minimise the amount of dust, such as tar macadam, asphalte, &c., would be prohibitive, and the attention of engineers has, therefore, been directed towards less costly methods.

Dust Palliatives.—In order that these may be successful, road surfaces must be thoroughly swept and freed from dust and the work of treating the surface carried out in fine, dry weather; otherwise the first heavy vehicle passing over the treated area will begin the work of destruction and in a short time the whole surface will be rendered very unsatisfactory and present large quantities of objectionable, dangerous mud.

Crude Tar has been extensively used as a dust palliative with excellent results. Care must be exercised in the boiling of the tar, as more than 3 % of water in the tar causes trouble during the boiling. The tar is heated to about 200° F., poured on the road, and then brushed into the surface, or spread by the aid of special machines. After the surface has been thoroughly treated, fine chippings are sprinkled over it—these being more suitable than sand. The action of the traffic causes the tar and chippings to form an impervious cushion on the surface of the road. The work should be carried out during warm weather. The cost works out at 1*d.* to 3*d.* per super yard. A good and effective method, and one which adds considerably to the life of the road, is to cover the surface with tar at the beginning of the summer and another coat in September, this method keeping the tarred cushion surface of the road in good condition during the winter, thereby making it easier to prepare the surface for the next summer's coat of tar.

Distilled Tar, from which the light oils and other compounds have not been extracted, is an exceedingly good dust preventer.

Distilled tar thinned by the addition of the residuums of petroleum oils in the proportion of 1 pint of petroleum to 2 gallons of coal tar is a good palliative, when mixed and applied cold. The treated surface should be sprinkled with fine chippings.

The same preparation with the addition of 1 pint of lias lime to the above proportions of petroleum and tar gives a thicker material which is almost as readily applied.

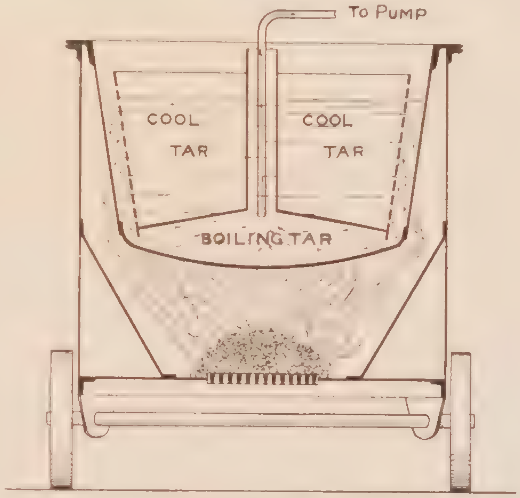
Carburetted Water-gas oil Tar.—This material is largely used in many districts where water-gas is manufactured. It is a much thinner liquid than coal tar, and can be sprinkled over the surface by means of an ordinary water cart. Heating is not necessary, it being applied cold. Fine chippings should be sprinkled on the surface.

Before treating of other palliatives, a word or two may be necessary about the boiling and distilling of crude tar. Care must be exercised in the process so that the material is not burnt or overheated. The water will rise to the surface and can then be removed by the use of a flat tin shovel. Overheating destroys

the essential oils in the tar and the work invariably results in failure.

Apparatus for Spreading Tar.—There are many machines for spreading tar, that have from time to time been placed upon the market. In smaller districts, where economy has to be exercised, it will be found that an ordinary street watering cart, fitted with a special tar spraying attachment in place of the sprinkler box, will be found useful, where the work is finished by the hand broom. Where only small quantities of work have to be done, a small apparatus such as the Simeon's tar-spraying and painting machine, or the machine supplied by the P. A. S. Distributors, Ltd., will answer the purpose. The latter machine is also capable of doing large quantities of work, and an experiment recently witnessed by the writer proved highly satisfactory. The cost of the machine is about £45. It is claimed by the manufacturers that boiling over of the tar is prevented. The Figure opposite is a rough line section through the boiler. The tar is placed in the internal section and percolates through perforations in the sides into the lower cavity of the external drum. The tar in this section when brought up to the required heat is drawn up the pipe and pumped by a hand pump into the distributor. This distributor has three or four sprays attached to an arm. This arm is attached to a single wheel which is worked by one man. By this arrangement, the man working the sprays can walk forward and keep to a line, no portion of the work having to be traversed by the man. Each spray will cover about 15 in. at each application, the combination of four covering about 4 ft. The cost of the tar and men's time spreading, fuel, carriage, &c., is about 3*d*. per super yard.

The machine which has given the best all round satisfaction was invented by Mr. Thomas Aitken, a gentleman who has given the subject of road construction more than ordinary attention, and whose tar-spraying plant has received the highest commendation. The "Tarspra" apparatus can be attached to an ordinary water van, drawn by either horse or tractor. This apparatus is constructed with an air receiver, into which air is pumped and kept at a constant pressure of 100 lbs. per square inch on the pressure gauge. Tar is then pumped into this receiver, increasing the pressure to about 220 lbs. The tar is sprayed on the road through a series of nozzles at a constant pressure of about 200 lbs. per square inch.



SECTION OF
PATENT "CANTAR," CONTINUOUS-HEATING.
SAFETY TAR BOILER

Oils.—Oil has been largely used as a dust preventer, petroleum being used some eight or nine years ago in America. The oil should be highly heated and put on the road during a very hot day, and afterwards covered with sand. Undoubtedly the best method is to treat it in the same way as a tar binder, a hard and firm covering being thereby obtained. Other coatings of oil can then be sprinkled on the surface to fill up the interstices remaining, and to give a smooth impervious surface. All petroleum oils are not satisfactory, and only those should be used which have an asphalte base.

It has been contended that when the wet season commences, the surface thus treated becomes very greasy, and objectionable mud is formed, necessitating thorough cleansing of the road surface.

Proprietary Preparations. — There are many patent preparations for dust prevention on the market, but only a few can be mentioned.

"Akonia" is the patent process of Mr. Dan de Liebhaber, and has been used with considerable success in a large number of districts. The following advantages are claimed for this material by the patentee:—

"Akonia" is cheaper, in most cases, than ordinary watering when applied at the rate of 250 applications a year. It is not only a dust preventer, but also acts as a road preserver and improver, by rendering the surface hard and smooth, thereby diminishing the disintegration of the macadam, and reducing the cost of scavenging. It is absolutely odourless, and free from emanations of any kind, uninjurious to health, does not damage tyres, metal, clothes, horses' hoofs, &c., or render the road slippery and cloggy.

It does away with the mud which invariably follows ordinary watering, and renders the road less muddy in wet weather. It requires no special appliances beyond an ordinary water cart, and can be kept for any length of time without losing its properties.

"Hahnite" is an insoluble liquid, which oxidizes when sprayed on to the road and forms an impervious and durable coating over the surface. It is claimed for "Hahnite" that it preserves the road, causes no injury to tyres, varnish, horses, or pedestrians, reduces the sound of traffic, acts as a disinfectant, prevents dust from rising, and minimises the formation of mud.

The use of this material compares favourably with ordinary street watering, and is applied to the road by a street watering cart.

Calcium chloride, which is manufactured at Northwick, Cheshire, is an excellent dust preventer. A small quantity of these crystals are placed in an ordinary watering cart, and allowed to dissolve in the water, thus forming a cheap dust palliative capable of producing good results, and of considerably reducing the cost of watering. (*See* "Road Watering.") R. H. B. & F. L.

Earth Closets.—Useful apparatus in the country, but unsuitable for use on a large scale or in populous districts, owing to the quantity of suitable earth required. Where water-closets are not practicable and the conditions are favourable, earth closets form the best substitutes, as the earth made use of not only keeps the excreta dry, but also deodorises it and disintegrates the organic matter and converts it into the condition in which it naturally exists in fertile soil. It is essential that the earth used should be suitable. It must be dry, finely sifted, and of a loamy nature, and from 1 to 2 pints must be spread over the excreta whenever the closet is made use of. An earth closet may simply consist of a seat fixed over a suitable receptacle, which is easily removed for emptying; the earth being in this case stored in a box and applied by hand with a trowel. A better apparatus is that in which the earth is applied automatically, as in the case of Moule's earth closet. In this a hopper is provided behind and above the seat capable of storing a sufficient amount of earth to last for some little time. Connected with this is a valve into which a measured quantity of earth falls, and which, being worked by a handle or by a lever connected with the seat, distributes the earth over the excreta when the handle is pulled or a person rises from the seat. When the handle is released or a person again sits upon the seat, the valve is recharged with the requisite amount of earth. No moisture other than that of the excreta and urine should be admitted to the closet. The apartment in which an earth closet is fixed should not have any direct communication with a dwelling. It should be well lighted and ventilated, and should be provided with an impervious floor raised some few inches above the ground level.

Economisers or Feed-Water Heaters.—Accessory appliances used in connection with steam boiler plants for the purpose of effecting a saving in fuel by utilising the waste heat in the flues for the purpose of heating the feed-water to the boiler. This object is achieved

in different ways—(*a*) by intercepting and utilising part of the heat of the gases from the boiler furnaces as soon as they leave the boiler; (*b*) by passing the feed through a vessel jacketed with exhaust steam, or using live steam in a similar manner. In principle, the "economiser" is really a supplementary boiler working within a low range of temperature and whereby a saving of fuel can be secured, say, from 10 to 15 %. For example, a boiler working at a steam gauge pressure of 150 lbs. per square inch with boiler-feed at 32° F., will consume 1,193 thermal units per 1 lb. of water evaporated, as compared with 1,013 units when using feed-water at 212° F., thus showing a saving of 15 % of the heat required. To secure the greatest real economy the temperature of the feed-water should be at a maximum with a minimum of fuel-cost. One of the best-known appliances for realising the advantages to be gained by the first method (*a*) is "Green's fuel economiser," which is a flue-heated feed-water heater. It consists of sections or rows of cast-iron tubes ($4\frac{1}{2}$ in. diameter by 9 ft. long) fixed in an enlargement of the main flue. The accumulation of soot which takes place on the pipes is removed by slow-moving scrapers (the invention of Mr. Green) upon their external surfaces. The size of economiser required for any given plant is calculated on the evaporative capacity of the boilers, but approximate rules such as the provision of one pipe for every three I.H.P., or 4 pipes per ton of coal per week of 56 hours, are useful guides. The hot flue gases may be reduced in temperature from 650° F. to 350° F., and the feed-water heated some 150° F. to 250° F. Each pipe has 10 sq. ft. of heat absorbing surface and a water capacity of $6\frac{1}{4}$ gallons. Another useful apparatus is the "Hudson economiser" which is also a steam condenser, is of simple construction, and has no tubes, so that renewal of parts is reduced to a minimum. This apparatus extracts the grease from the exhaust steam before coming in contact with the cold feed. The purified steam thus obtained comes in direct contact with the cold feed entering the top chamber of the apparatus through a spray, the water being nearly boiled. Softened water is thus obtained, free from oil, at from 200° F. to 210° F., for purposes of boiler feed. The apparatus thus possesses the further advantage of preventing incrustation on the interior of boiler shell or tubes.

Exhaust-steam feed-heaters are also largely used, and an average economy of about 15 % is obtainable between a cold boiler feed at 55° F. and water at 212° F. In the "Row feed-water" heater a patent indented tube is used which is claimed as being twice as efficient as an equal amount of plain tube surface. For good water, not liable to scale, the steam circulates around the outsides of the tubes through which the water passes. For bad water this order is reversed.

Efflorescence.—This is a term applied to a peculiar powdery substance which occasionally appears on the face of new brick or stone work. As a rule it arises from an excess of salts in the bricks or stone, which become dissolved in water from heavy rain. Usually the efflorescence consists largely of sulphate of magnesia. The cure is difficult, but a periodical washing down with diluted hydrochloric acid, applied by means of a sponge, is to be recommended.

Ejectors. — Hydro-pneumatic "ejectors," for lifting sewage by the employment of compressed air, now often replace centrifugal and lift pumps, and, in suitable circumstances, have many advantages for such work. The principle upon which the apparatus works will be understood from an inspection of Fig. 1, which is a sectional diagram of "Coombs" pneumatic ejector as installed for raising crude sewage, and other liquids, by compressed air. The apparatus consists of a wrought-steel or cast-iron body or container *C.*, provided with inlet and outlet sewage flap valves *I. V.* and *O. V.*, sluice valves *S. V.*1 and *S. V.*2, for disconnecting the ejector, and two floats *T. F.*, and *B. F.*, which operate the automatic valve *A. V.* which controls the

supply of compressed air and the exhaustion of same after ejection of the sewage. In actual work the sewage flows from the gravitation sewers into the container *C.*, through the inlet flap valve *I. V.* until it is full, when the top float *T. F.* rises and opens the automatic valve *A. V.* to the compressed air supply, closing it to exhaust at the same time. The sewage is then discharged through the outlet flap valve *O. V.*, by the pressure of the compressed air, and the body of the ejector is quickly emptied. When the container *C.* is nearly empty, the bottom float *B. F.* falls and closes the automatic valve *A. V.* to compressed air supply, and at the same time opens the valve to exhaust, so allowing the compressed air to escape, after which a fresh charge of sewage flows into the container, thus beginning another cycle of operations as above described. The working of the apparatus is automatically repeated so long as there is a flow of sewage and a supply of compressed air. Attendance is only required at the ejector chamber for periodical inspection. The rate of discharge depends upon the time of filling, and the ejector will automatically adapt itself to the variations of sewage flow. Ejectors are sometimes placed in pairs, and may be arranged to work either independently or alternately so as to give a continuous delivery of sewage.

The compressed air for actuating the ejector is commonly produced at some central station and transmitted to the ejectors in different parts of the district as may be required. The air mains consist of cast-iron pipes, as used for water supply purposes, with spigot and socket joints, caulked with lead and yarn. Generally speaking, the use of compressed air as a motive power is not found economical in fuel costs, but this does not apply to the same extent in the case of ejectors lifting sewage as ordinarily applied. The total cost under all heads of expenditure must be considered in estimating the value of the system in any given case. For ejector work, low pressures such as from 15 lbs. to 25 lbs. are the normal conditions met with, and the percentage of loss is much less than in the case of higher pressures. For greater pressures two-stage compression is necessary, but ejector work is generally below the limit for the advantageous employment of stage compression. Considerable improvements have been made of recent years in the compressors employed, and the modern high-speed compressor, with mechanically-operated valves, gives a much greater efficiency than the earlier type of low-speed compressor fitted with lift-valves. In the drainage of many towns it is an advantage to be able to divide the area into a number of independent drainage areas, and to such a condition the ejector system favourably lends itself, as the ejectors can be conveniently worked from one central compressor station. The system is applicable, in general, where low-level sewage has to be

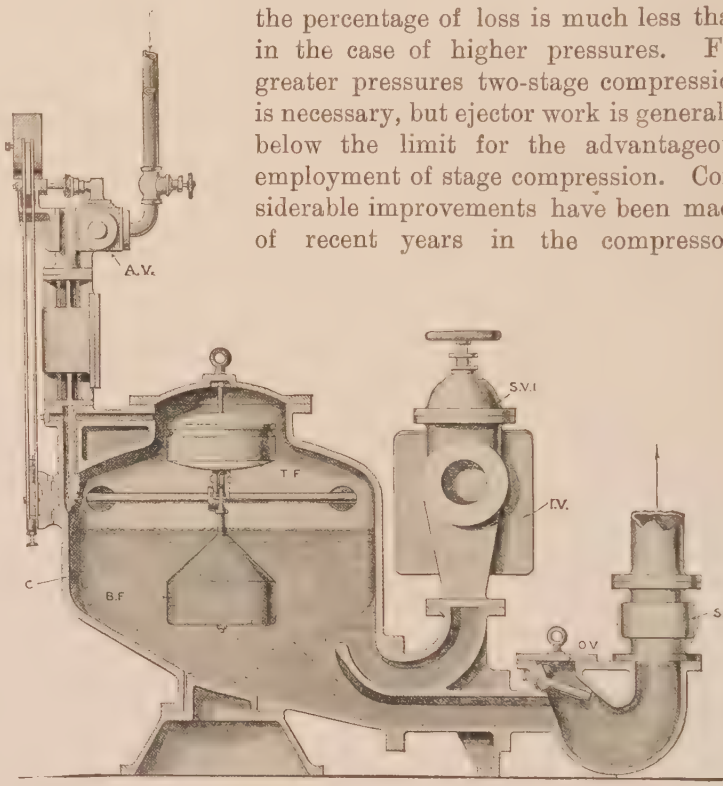


Fig. 1.—"Coombs" Pneumatic Ejector. (Daniel Adamson & Co.)

lifted to higher parts of the district, into intercepting or outfall sewers, for delivering sewage in low-lying areas out to sea during any state of the tide, and also in level country where to secure self-cleansing gradients deep and expensive cuttings would be involved in a purely gravitation scheme of drainage. The mode of fixing an injector in a brick underground chamber and connecting it with the gravitation sewer on the one side, and with a rising or delivery main on the other, is shown in Fig. 2.

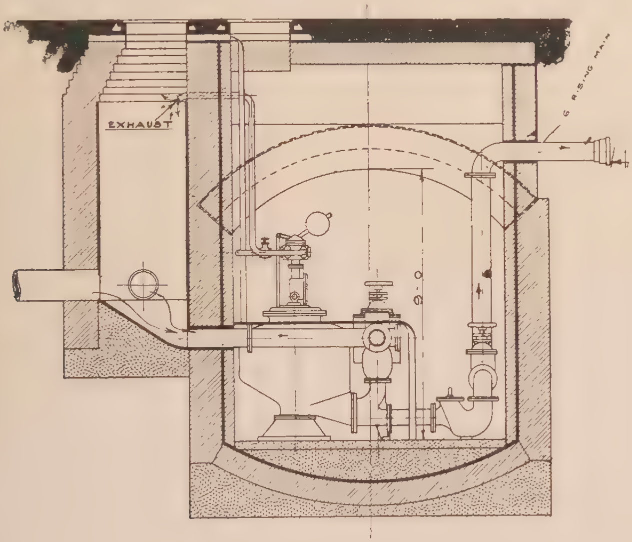


Fig. 2.
"Coombs" Ejector in Chamber. (Daniel Adamson & Co.)

In the actual working of the ejector, there are certain advantages which tend to facilitate the raising of sewage by this method. For example, there are no parts liable to be injured by the action of the sewage or of grit upon them, and the working parts are few and not likely to get out of order. The sewage inlet and outlet valves are in excess of the full area of the delivery pipe, and a free passage is given for the carrying away of all solids which drop direct into the delivery passage sloping towards the outlet, and are thus removed by the first flush of liquid from the container. Previous screening of the sewage is thus unnecessary, an advantage over pumping plants where periodical cleansing of screens and sump wells is essential.

Electricity. — **Introduction and Definition — Components of Electricity — Electric Lighting — Flame Arc Lamps — Incandescent Lamps — The Electricity Works — Systems of Charging for Electricity—Electricity Meters—Transforming Stations and Apparatus—Electric Motors.**—No useful purpose would be served by endeavouring in this article to define and explain the term electricity in the sense in which it is used by the physicist. As used by the engineer, electricity has come to denote a form of energy. The independent use of the word in these two senses rarely leads to misunderstanding. The physicist in his "electronic theory of matter" states that the atoms of matter themselves are made up of "electrons" (hypothetical concentrated units of negative electricity); each aggregation of electrons being surrounded by a sphere of positive electricity, and that, consequently, matter, in its last analysis, is identical with electricity, and consists of nothing else. While the physicist appears to regard this profound alleged knowledge with considerable satisfaction, it is evidently of very little practical use to the engineer or to the layman, who have for many years considered electricity to be something which, consumed in sufficient quantities, serves to provide light and heat, and to propel tramcars and railway trains, and to drive machinery in workshops and factories. Light, heat, and work are well known to be forms of energy. It is furthermore well known that energy may be converted from one form into another. To the engineer and layman, electricity is also a form of energy. At present, the engineer deals with electricity as something which can be bought and sold in definite quantities, and his purposes are sufficiently served, therefore, by simply regarding electricity as a form of energy.

Components of Electricity.—Electricity may be sub-divided into three components: (1) Pressure, (2) Current, (3) Time.

In engineering calculations the units in which these components are expressed are—

The unit of pressure = the volt.

The unit of current = the ampere.

The unit of time = (usually) the hour.

Electricity is used commercially in one or other of two forms:

I. Continuous electricity.

II. Alternating electricity.

In the first of these, the direction of the current is constant, whereas in the second the current alternates in direction many times per second. A detailed consideration of the theory of these two forms of electricity cannot be undertaken in this article, but the appropriate use for each form will be set forth in a later section of it.

The following explanations of terms, although they should be taken as applying strictly only to continuous electricity, are in most instances substantially true of alternating electricity. Any quantity of electricity is made up of the product of the three components, pressure, current, and time. The unit of electricity is the kilowatt hour, sometimes called the Board of Trade unit, or merely the unit. It is preferable to employ the term kilowatt hour (kw. hr.).[1] A quantity of electricity in kilowatt hours is equal to 1,000 times the product of the pressure in volts, the current in amperes and the time in hours. In other words: Kilowatt hours = 1,000 × volts × amperes × hours. The above is the equation for the quantity of energy.

Power is the rate of expenditure or transformation of energy. Consequently power is expressed in kilowatt hours per hour, *i.e.*, in kilowatts. The power equation is thus obtained by dividing both sides by the time in hours. We thus have for the power equation:

$$\text{Kilowatts} = \frac{1{,}000 \times \text{volts} \times \text{amperes} \times \text{hours}}{\text{Hours}}$$

i.e., kilowatts = 1,000 × volts × amperes.

Thus when energy is being delivered over a circuit at the rate of one kilowatt-hour per hour (or of one "unit" per hour) the power being transmitted is one kilowatt.

One kilowatt = 1·34 horse power.

One kilowatt-hour = 1·34 horse power hour.

One kilowatt = 1,000 watts.

Since kilowatts = 1,000 × volts × amperes
watts = volts × amperes.

In the case of a conductor of given dimensions and material, a certain pressure in volts is required to send through the conductor a current of one ampere. The conductor is said to have a certain resistance. This resistance is expressed in ohms, and is equal to the volts divided by the amperes. Thus:

$$\text{Resistance (in ohms)} = \frac{\text{Pressure (in volts)}}{\text{Current (in amperes)}}$$

or

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes.}}$$

This is known as Ohm's law, in honour of Dr. Ohm, its discoverer.

Electricity is employed for obtaining work, light, and heat; *i.e.*, energy in the form of electricity is converted into energy in these other forms. The most extensive of these commercial applications of electricity is to lighting, but during recent years the electrical operation of tramcars has also assumed great importance. Electricity, as a source of mechanical energy, is appropriate not only for propelling tramcars, but for many other industrial processes, as for driving mills and workshops, and for dockyards and harbours. The application of electricity to heating and cooking is now reduced to a commercial basis and bids fair to soon assume an importance commensurate with the use of electricity for lighting.

Electric Lighting.—Electric lamps may be divided into two great classes:

I. Arc Lamps.

II. Incandescent Lamps.

Each of these classes comprises a large number of types, and it will be necessary to restrict the scope of our inquiry to the most modern representative of each class. I. The so-called "flame" arc lamp has only come into extensive use during the last three years.

[1] It has been suggested that the term "kelvin" be employed in place of the term "kilowatt hour."

It is far more economical than any other type of arc lamp and has largely supplanted other types. II. During the same period, *i.e.*, during the last four years, a great advance has also been made in incandescent lamps. This has related to the extensive commercial introduction of the metal lamp. This is a lamp with a metallic filament and it is rapidly supplanting all forms of incandescent lamps with carbon filaments. The metal lamp consumes, for a given candle-power, less than one-third as much energy as is consumed by the carbon lamp; consequently, in spite of its somewhat greater first cost, its use is attended by large ultimate economy.

Flame Arc Lamps.—One of the several excellent types of flame arc lamp now on the market is illustrated in Fig. 1. The widest and most appropriate field for the use of flame arc lamps is in the lighting of streets, parks, docks, railway yards and other open spaces, and also for the interior illumination of large halls, warehouses, theatres, factories, workshops and railway stations. In Fig. 1 *A. A.* are two carbon rods between the lower extremities of which, the flaming arc is formed. The carbons are slowly consumed and in order that the arc may remain at the same point, the carbons as they burn away are slowly fed downward by means of the electromagnetic mechanisms seen in the upper part of the case of the lamp. When operated on circuits supplying continuous electricity, it is customary to run two such lamps in series from a 110 volt circuit, and four lamps in series from a 220 volt circuit. The lamps are built for various currents; 10 amperes is, however, the current usually employed. Thus two such lamps consume

$$110 \times 10 = 1{,}100 \text{ watts}$$

or 550 watts per lamp.

A 10 ampere flame arc lamp, operated from a circuit of continuous electricity, gives out about 2,100 candle-power. Thus the consumption is

$$\frac{550}{2{,}100} = 0{\cdot}26 \text{ watts per candle-power.}$$

A customary size for the carbons of such a 10 ampere flame arc lamp is 500 mm. long, and 9 mm. and 8 mm. diameter respectively for the positive and negative carbons. These carbons must be renewed about every 11 hours at an average cost of some 6*d.* per pair of carbons. This cost is made up of, say, 4*d.* for the price of the carbons and 2*d.* for the labour of "trimming" the lamp, *i.e.*, replacing and adjusting the carbons, cleaning the globe, and maintaining the lamp in good condition. Thus the cost per lamp per 1,000 hours for carbons and trimming, is some 45*s.* The price of the electricity may be anywhere from 1*d.* to 3*d.* per kw. hr. In 1,000 hours the lamp consumes

$$1{,}000 \times 0{\cdot}550 = 550 \text{ kw. hr.}$$

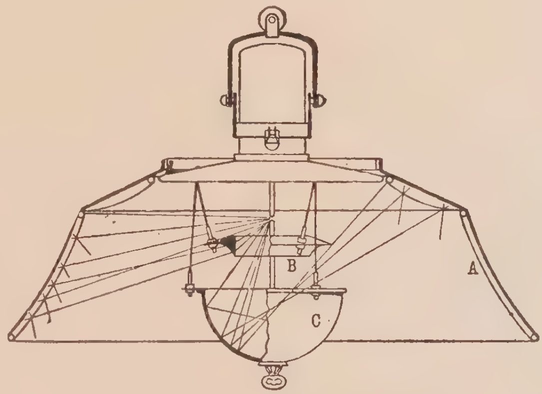


Fig. 1.—Section of Flame Arc Lamp.

Thus for total cost per lamp per 1,000 hours we obtain the values set forth in the next to the last column of the following table, and the total cost per candle-power (c.p.) per 1,000 hours is given in the last column:—

Price of Electricity in Pence per kw. hour.	Cost of Electricity in Shillings per Lamp per 1,000 hours.	Cost per Lamp of Carbons and Trimming, in Shillings per 1,000 hours.	Total Cost of 55 Volt 10 Ampere Flame Arc Lamp per 1,000 hours, in Shillings.	Cost per c.p. per 1,000 hours, in Pence.
1	46	45	91	0·52
2	92	45	137	0·78
3	138	45	183	1·05

The above costs are for the naked arc. If the arc is contained within globes, the

candle-power is decreased by some 15 % for clear glass, and by some 30 % for opal globes and the cost per candle-power is correspondingly higher. The illumination is given in terms of the mean hemispherical candle-power. If operated from circuits of alternating electricity, flame arc lamps are considerably less economical. With the older forms of arc lamps the inferiority on alternating circuits is still more marked.

The first cost of a flame arc lamp is usually about £8 to £10, and since there is nothing in their construction to preclude a life of some 10 years, the charge for interest and depreciation but slightly affects the result. Taking interest and depreciation as amounting to 30*s.* per lamp per year, and assuming that the lamp burns 3,500 hours per year, we arrive at the annual cost per year set forth in the following table :—

Price of Electricity in Pence, per kw. hour.	Cost of Electricity, Repairs, and Maintenance in Shillings per Lamp per Year of 3,500 hours actual burning.	Capital and Renewal Charges, in Shillings, per Lamp per Year.	Total Cost, in Shillings, per Lamp per Year of 3,500 Hours actual Burning.	Cost in Pence per c.p. per year of 3,500 hours actual burning.
1	318	30	348	2·00
2	480	30	510	2·90
3	640	30	670	3·83

It is very difficult to generalise as to the number of lamps required to afford satisfactory outdoor illumination. A correct idea is best obtained by examples, a couple of which relating to London streets are given in the following table :—

Name of Street.	Distance between Lamps.	Height above Ground.	Width of Street.	Type and Capacity of Lamp.
Holborn	230′ on either side of street	20½′	82½′	10 amp. white magazine flame arc mounted on post.
Cannon Street	165′ in middle of street	28′	64′	11 amp. yellow flame arc with central suspension.

A suitable illumination may be obtained by 11 ampere flame arc lamps with yellow flame carbons, spaced some 250 ft. apart on either side of the road and 20 ft. from the ground, or some 150 ft. apart in the centre of the road and about 28 ft. from the ground.

It has been stated that the carbons must be renewed by hand about every 11 hours, but recent developments in "magazine" lamps have extended this period to about 40 hours. A magazine lamp employs 6 to 9 pairs of carbons, which automatically, pair by pair, take the place of the burnt pair. This saves the necessity of trimming when each pair has burnt away. It has the further advantage that the carbons may be burnt to a stump. By the use of magazine lamps the cost of trimming per 1,000 hours given in the table on p. 151, may be reduced some 15 % whilst the total cost per 1,000 hours may be reduced some 3 to 8 % depending upon the price of electricity per unit. The longer hours of burning of the magazine lamp is, however, of doubtful advantage for the reason that the light is better and the mechanism is kept in better condition when the attendant visits it frequently, cleaning the mechanism and the globes at each visit. The less frequent attention given to the magazine lamp is conducive to more rapid deterioration of the working parts.

Incandescent Lamps.—As already stated, the metal lamp is by far the most economical and satisfactory form of incandescent lamp. Formerly incandescent lamps were used almost exclusively for interior illumination, but since the advent of the metal lamp, it has also come into fairly extensive use for outdoor illumination, thus becoming a rival of the flame arc lamp, especially where it is of advantage to sub-divide an aggregate candle-power amongst many lamps. Taking into account the cost of renewing carbons it may be said that flame arc lamps are only economical in sizes of at least 1,000 c.p. per lamp, whereas economical metal lamps may be obtained in practically all sizes from 10 c.p. up to 400 c.p.

Let us first fix our attention on a 50 c.p. 220 volt metal lamp of any one of the excellent types now on the market. Such a lamp consumes about 1·3 watt per c.p. Consequently the total consumption per lamp is

$$50 \times 1{\cdot}3 = 65 \text{ watts.}$$

Owing to the greater effectiveness obtained by sub-division, 20 such lamps with an aggregate illumination of

$$20 \times 50 = 1{,}000 \text{ c.p.}$$

are fully equivalent to one 2,000 c.p. flame arc lamp, *i.e.*, to a flame arc lamp of the size which has been taken in the preceding estimate. The consumption of 20 lamps is $1{,}000 \times 1{\cdot}3 = 1{,}300$ watts as against only 550 watts for the 2,000 c.p. flame arc lamp. It will be conservative to estimate on replacing the metal lamps after an average of 1,200 hours in circuit. The price per lamp is 3·75*s.* This gives for the 20 lamps a renewal cost of

$$20 \times \frac{1{,}000}{1{,}200} \times 3{\cdot}75 = 63s. \text{ per } 1{,}000 \text{ hours,}$$

assuming the average life of each lamp to be 1,200 hours. The consumption per 1,000 hours for the 20 lamps will be 1,300 kw. hour. Thus for the total cost per 1,000 hours of burning, including renewals, we obtain the values given as follows for various prices per unit of electricity.

Price in Pence per Unit of Electricity.	Cost of Electricity in Shillings per 1,000 Hours.	Cost of Renewals in Shillings per 1,000 Hours.	Total Cost of 20 Metal Incandes. Lamps giving 1,000 c.p. for 1,000 Hours.	Cost in Pence per c.p. per 1,000 Hours.	Cost in Pence per c.p. per year of 3,500 Hours Actual Burning.
1	108	63	171	2·04	7·15
2	216	63	279	3·35	11·70
3	324	63	387	4·65	16·30

The above table is based on the use of lamps of 50 c.p. each, but there is the alternative of employing metal lamps having 400 c.p. per lamp, and consuming some 440 watts per lamp. We may take it that four such lamps, giving an aggregate c.p. of

$$4 \times 400 = 1{,}600 \text{ c.p.,}$$

will afford an illumination equivalent to the 2,000 c.p. flame arc lamp on the one hand, and to the twenty 50 c.p. metal lamps on the other hand. The cost of these lamps is some 19*s.* each, and their average life some 1,000 hours. We thus obtain the cost per year for running four lamps, as set forth in the following table:—

Price in Pence per Unit of Electricity.	Cost of Electricity in Shillings per 1,000 Hours.	Cost of Renewals in Shillings per 1,000 Hours.	Total Cost in Shillings, of 4 Metal Incandescent Lamps giving 1,600 c.p. for 1,000 Hours.	Cost in Pence per c.p. per 1,000 Hours.	Cost in Pence per c.p. per year of 3,500 Hours Actual Burning.
1	147	76	223	1·68	5·87
2	294	76	370	2·78	9·73
3	440	76	516	3·87	13·50

These 400 c.p. lamps differ slightly in form from the 50 c.p. lamps, in that they are fitted with Edison screw caps instead of bayonet fittings. The reason for this modification is that the manufacturers find the "Edison screw cap" more suitable for running on heavy currents than the ordinary bayonet holder. When comparing the running costs of these lamps with the equivalent running cost of the flame arc lamps, one must keep in mind that the candle-power of the arc lamp is considerably reduced by deposits on the inner globe, and this loss amounts, as stated before, to some 20 to 30 °/ₒ. In order, therefore, to maintain the apparent advantage in efficiency of the flame arc over the metal lamps, the globes of the arc lamp must be constantly cleaned—an item which will increase the cost of maintenance. On the other hand there is no diminution of light in the metal lamps, as the globes remain clear and the candle-power is maintained practically constant throughout their life. Moreover the life of the metal lamps taken above are conservative values, and it is very probable that 1,500 hours would be more in accordance with the facts. The field of interior illumination by electricity is now almost exclusively filled by the metal lamp. Data for the costs of 400 c.p. and 50 c.p. sizes have already been given. For interior illumination, however,

the great majority of lamps are nowadays some 25 c.p. each. The present market price of these lamps is about 3*s.* per lamp as against the price of 4*s.* per lamp of a year ago. The near future will doubtless witness further material reductions in the price of metal lamps. The first cost is of less consequence the higher the price paid for electricity. Thus taking at 1,000 hours the life of a 25 c.p. metal lamp, and its consumption at 1·3 watts per c.p., the total outlay per lamp per 1,000 hours of actual burning, for various prices of electricity, works out as follows :—

Price of Electricity per Unit.	Cost of 25 c.p. Lamp in Shillings.	Cost of Electricity for 1,000 Hours in Shillings.	Total Cost in Shillings per 1,000 Hours.	Total Cost per Lamp-hour in Pence.
1*d.*	3·0	2·70	5·7	0·07
2*d.*	3·0	5·40	8·4	0·10
3*d.*	3·0	8·10	11·1	0·13
4*d.*	3·0	10·8	13·8	0·17
5*d.*	3·0	13·5	16·5	0·20

The Electricity Works.—The building and apparatus where a portion of the energy of the coal is transformed into electricity is sometimes called the Generating Station, sometimes the Central Station, and sometimes, and preferably, the Electricity Works. If the area to be supplied is very limited in extent and in the immediate neighbourhood of the Electricity Works, it may be economical to employ sets in which continuous electricity is generated. Almost all modern Electricity Works are, however, equipped with electric generators supplying polyphase alternating electricity. This alternating electricity is transmitted at high pressure to suitably located sub-stations, where by means of motor generators, it is transformed into continuous electricity and distributed to the consumers in this form. This arrangement is indicated diagrammatically in Fig. 2.

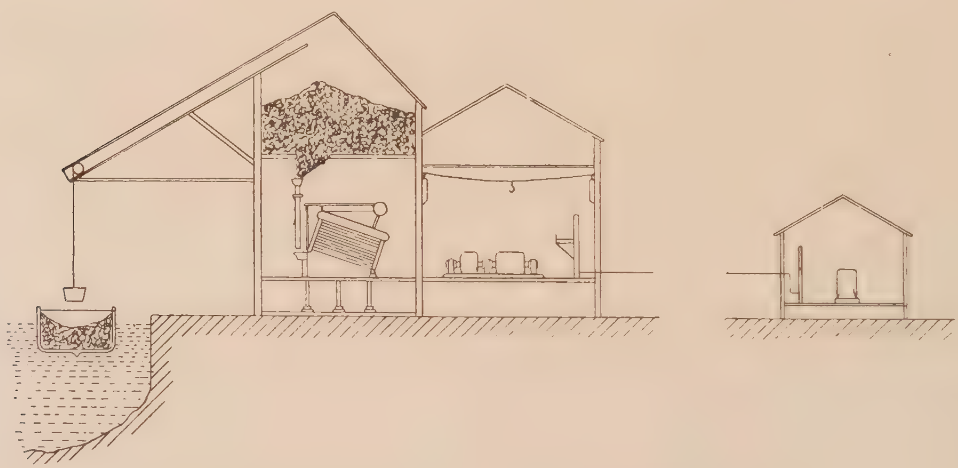
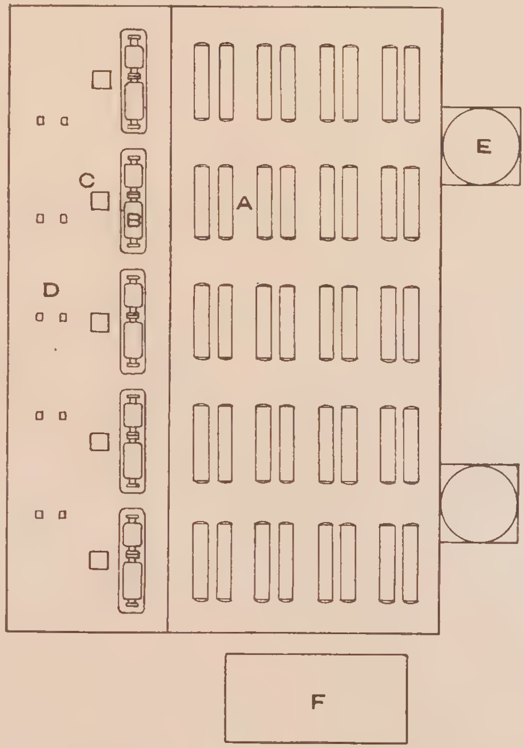


Fig. 2.—General Arrangement of Power Station and Sub-station.

The coal is brought to the electricity works by canal or rail. In the illustration, the coal is indicated as being transferred from a canal boat to a conveyer, by which it is deposited in large hoppers at the top of the boiler-room. In large works these hoppers often have capacity for 5,000 tons or more. The coal next passes through shoots from the hoppers to the automatic stokers under the boilers, sometimes passing through weighing devices interposed just before the coal reaches the automatic stokers. These stokers are adjustable, and

deposit the coal uniformly over the grate, and in the correct quantity. The correct adjustment of the supply of air is no less important, and is attained by the assistance of CO_2 recorders, which should constitute part of the equipment of all Electricity Works. The boilers should be of some one of the several excellent water-tube types which are now available. These are much more compact, and are in other respects more satisfactory than the fire-tube types formerly employed. Even with the most compact boilers, however, the boiler-room necessarily extends over a considerable area. The largest boiler which may at present be considered as thoroughly standard, and obtainable from any one of several reliable manufacturers, has a normal evaporative capacity for raising 15 tons of steam per hour "from and at" 100° C., and can, when forced, supply at the rate of over 20 tons per hour for short periods. The superheating tubes are generally incorporated in the boiler, and may be considered as a component. Such a boiler's normal capacity, when supplying steam at 13 atmospheres and with 50° C. of superheat, which are conditions which represent approved practice, and when the feed-water temperature is 50° C., is only 12·5 tons of steam per hour, since this quantity is equivalent to 15 tons "from and at" 100° C.

The outputs of Electricity Works are best expressed in millions of units (*i.e.*, of kilowatt hours) per year. These outputs range from one million units per year for the Electricity Works of a small town, up to 100 million units and more per annum for Electricity Works in large cities. A Works of the latter size would require, as an average, some 100 tons of steam per hour and for peak loads this would usually rise to over 200 tons per hour. Consequently, in order to have sufficient spare plant, at least 20 of the above described boilers would be required. These would be arranged in groups of four, and each group would supply steam to a steam turbine of some 8,000 h.p. capacity. There would be five of these steam turbines, and each would drive a 6,000 kw. polyphase alternator. All this apparatus would preferably be arranged in five distinct groups, as this gives additional certainty of absolutely uninterrupted supply. Each of these groups also comprises a surface condenser. Outside of the station are located cooling towers. The switch gear may be located either at one side of the engine-room or in a separate



A — Boilers.
B — Turbo-Alternators.
C — Exciters.
D — Switchboard Gallery.
E — Chimneys.
F — Cooling Tower.

FIG. 3.—General Arrangement of Electricity Works.

building. In modern plants the switch gear is controlled by relays from an operating desk. By this means the massive gear for high pressure and large amounts of power may be perfectly controlled by the suitable manipulation of the low-pressure relay circuits.

The general arrangement of the Electricity Works is indicated diagrammatically in Fig. 3.

It would exceed the limits of this article to

enter upon the discussion of all the machinery required in an electricity works. Considerable interest, however, naturally arises in regard to the significance to be attached to the rating ascribed to the electricity generators. The capacity stated on the name-plate of the set is of little use in judging its capacity. Although generating plant is always sold to some sort of a specification, there is, as yet, no widely acknowledged standard basis of rating as regards, for instance, temperature rise and overload. Thus we are not learning much when we are informed that the aggregate rated capacity of the generating sets installed in any particular Works is so many kilowatts. It has consequently come about that little or no useful knowledge is imparted when it is stated that the capital cost of an Electricity Works is £25 per kilowatt of plant installed. It is rarely stated whether by the kilowatts capacity is meant the aggregate capacity of the plant installed or only the lesser capacity arrived at after deducting the portion to be considered as a reserve. There are also the alternatives that the kilowatts capacity may be intended to mean either the average power or the maximum power delivered from the Works.

A suitable groundwork on which to prepare a specification for the generating sets is that, on the basis of the rating assigned to them, they shall be capable of dealing with a 25 % overload for 1 hour, and with a 50 % overload for 5 minutes without detriment to any part of the steam-electric set, and that when continuously operated at the rated output, no accessible part of the electric generator shall sustain a temperature rise, as thermometrically determined, of more than 40° C. above the temperature of the engine-room in the immediate neighbourhood of the generating set.

There are very many other matters, such as the steam consumption, the mechanical construction, insulation, pressure regulation, uniformity of angular rotation, &c., which must be carefully stipulated in the detailed specification, but for the purposes of the broad outlines appropriate to this article, a discussion of these details would be out of place.

The load factor is the ratio of the average power delivered from the works during the entire 8,760 hours in the year, to the maximum power delivered at any time during the year. For a miscellaneous load made up of lighting, power, and tramways, the load factor will usually be not less than 25 % nor more than 40 %. Under favourable conditions, when a considerable percentage of the power is required for certain electro-chemical or thermal processes, such as the manufacture of calcium carbide or aluminium, the resultant load factor at the outgoing cables from the Electricity Works may be even 60 % or more, though large miscellaneous undertakings with a load factor of even as much as 50 % are still very exceptional.

On the basis of these heating and overload requirements, an Electricity Works will, according to the magnitude of its output, require to comprise electricity generating sets of the following aggregate rated capacity:—

Rated Output of Station in Megakelvins per Year.	Aggregate Rated Capacity in kw. of Generating Sets Installed, for following Load Factors:		
	0·60	0·40	0·30
1·00	276	407	528
5·00	1,320	1,900	2,470
20·0	5,070	7,500	9,790
100·	24,400	34,000	45,200

In the following table are given representative values for the total cost of such Electricity Works when built in accordance with best modern practice.

Rated Output of Station in Megakelvins per Year.	Total Cost of Electricity Supply Stations, in £, for following Load Factors:		
	0·60	0·40	0·30
1·00	10,400	12,500	13,850
5·00	33,700	46,750	54,250
20·0	95,200	136,000	175,000
100·	364,000	505,000	636,000

In addition to the capital outlay for the Electricity Works, there is the capital outlay for the conductors by which the electricity is conveyed to the consumer and for all the works, such as subways or towers, required in the construction of this transmission line. Usually also there will be small intermediate stations, termed sub-stations, in which motor generators are installed, and where the electricity which has been transmitted at the high pressure required in the interests of low outlay for conductors, is transformed into electricity at the low pressure desired by the consumer. The costs of the system between the Electricity Works and the consumer's premises vary widely according to the distance, the number and distribution of the consumers, the amount of electricity required by the consumers individually and collectively, the extent to which the times during which the various consumers' requirements for electricity overlap with one another, and on several other conditions. In general, these costs will aggregate from one-half of the cost of the electricity works up to, and some times even in excess of, the cost of the Electricity Works.

The aggregate of the capital and depreciation costs of the Electricity Works and of the distribution system, which may be termed the capital costs, taken together with the operating costs, lead to a cost per unit delivered at the consumer's premises, which, averaged for all the consumers, may, with coal at 10*s*. per ton, and with a load factor of 35 %, so far as concerns the general order of magnitude, be taken as requiring the following average price per unit :—

Annual Output from Electricity Works in Units (*i.e.*, Kilowatt Hours per Annum).	Average Price in Pence per Unit.
5,000,000	1·3
10,000,000	1·0
20,000,000	0·70
50,000,000	0·60
100,000,000	0·55

Estimates indicating lower average prices are sometimes seen, and the results are, from their very nature, greatly dependent upon very many special circumstances of each case, such as the terms on which capital may be obtained, facilities for obtaining ample and cool condensing water at a low price, accessibility to rail or water-ways as affecting not only the price of fuel but also the price of machinery as delivered on the site, wages, intelligence and disposition of employees, enterprise and knowledge on the part of the management; nature, extent, and geographical distribution of the industries in the region, and on various other conditions.

It should not be concluded that all consumers will pay this average price. On the contrary, an equitable distribution of the charges allocates to certain consumers a price of two or three times the average price, while the supply to other consumers is profitable, even at half or less of the average price.

The equitable price to any particular consumer will be less—

1. The less the distance to which his electricity must be transmitted.

2. The greater the number of consumers who can be supplied over the same conducting system.

3. The less the extent to which the consumer's load overlaps the load of other consumers.

4. The greater the amount he consumes per annum.

5. The greater the annual load purchased from the Electricity Works by the consumers collectively.

6. The higher the load factor of this aggregate load.

7. The higher the load factor of the consumer's own load.

Many other conditions must also be taken into account. Thus, if the consumer requires electricity in the same form and at the same pressure as that at the outgoing cables from the Electricity Works, he will pay a much lower price than if he requires the electricity

transformed in pressure or in kind, or in both respects.

Systems of Charging for Electricity.—There are numerous methods whereby consumers are charged, but the following methods are the more common ones :—

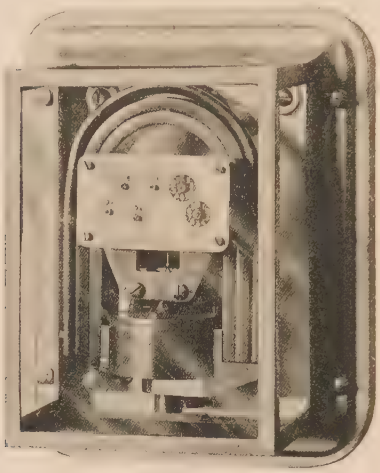


Fig. 4.—Section of Typical Meter.

(1.) Flat rate. This method requires the consumer to pay a constant price per unit, irrespective of his load factor. For private lighting this rate generally lies between 3*d.* and 6*d.* per unit, and for power the limits are generally of the order of 1*d.* and 2*d.* per unit.

(2.) Fixed minimum consumption rate. This method requires the consumer to pay a certain sum each year irrespective of his load, in addition to a certain price per unit for each unit consumed. This system is generally used for private lighting, when there is only one customer, or perhaps a few, being supplied over a long and otherwise "dead" main. It is a fairly representative method, however, of charging for electricity used for power purposes. This system is very similar to the "Manchester system" introduced by Dr. Hopkinson. The price charged under this system was made to depend upon a fixed rental plus a proportional charge for energy, the fixed rental being determined by the number of 8 c.p. lamps, or the equivalent thereof, wired.

(3.) Maximum demand rate. This is sometimes called the "Wright system," or "Brighton system." This rate charges a high price (generally 7*d.* or 8*d.*) per unit for a consumption equivalent to the use of the maximum demand for a certain time (generally 1 hour per day), and a low price (generally between 2*d.* and 4*d.*) per unit for any energy consumed beyond this amount. In this system a "maximum demand indicator" is introduced into the consumer's circuit. For an example, suppose the consumer's quarterly (say 90 days) consumption is 1,500 units, and the indicator shows a maximum demand of 10 kilowatts, there will be $10 \times 90 = 900$ units to be charged at the high rate (7*d.* or 8*d.*), and only $1{,}500 - 900 = 600$ units to be charged at the low rate (2*d.* to 4*d.*).

(4.) Sliding scale rate. The customer is required to pay a net flat rate for the first 1,000 units (or other quantity) consumed per quarter. For each successive 1,000 units an increasing discount is made from the flat rate up to a certain total consumption,

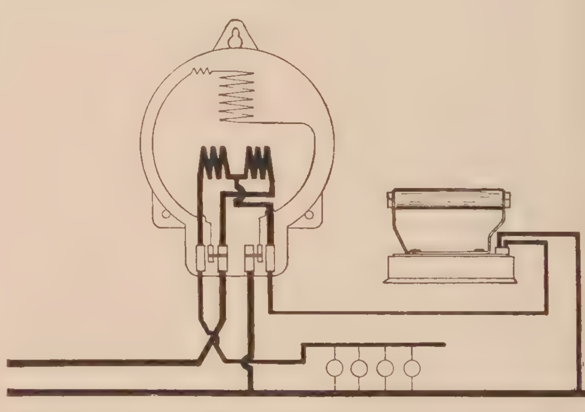


Fig. 5.—Diagram showing Wiring of the "Adnil" One-meter System for Lighting and Power Circuits.

after which the price per unit remains constant.

Electricity Meters.—It is not sufficient for a consumer of electricity to be acquainted only with the current and pressure which he

may be using, but he must also be able to ascertain the total energy delivered to him, irrespective of the current and pressure at any particular time. An instrument capable of measuring this energy is termed an "electricity meter." A rough classification of electricity meters is afforded by the nature of the circuit on which they are intended to be employed. Thus there are those that can be employed on

1. Continuous electricity circuits only;
2. Alternating electricity circuits only;
3. Both continuous and alternating electricity circuits.

They may again be classed as

1. Motor meters,
2. Clock meters, and
3. Electrolytic meters.

All three of these types are extensively used. Practically all modern meters are of the watt hour type, frequently called integrating or recording watt meters. These register the use of electricity in watt hours by means of dials and pointers. Sometimes these dials are arranged to read directly in units (1,000 watt hours), and parts and multiples of units. Each dial is divided into ten divisions, and one revolution of the pointer of any dial is equal to one division of the dial of next greater value. The dials are most conveniently and accurately read in the order beginning with that having the lowest capacity, and in recording the reading, the result should be written from right to left. In Fig. 6 are given several dials which will serve as an illustration in reading. In this case the reading is 8839·5 Board of Trade units. The accuracy of meters generally lies between 1 and 2 % slow or fast. Three per cent. either side should be considered the maximum allowable.

A type of electricity meter which has come extensively into use, especially with small consumers, is the "prepayment meter." With this meter the consumer cannot possibly use more light than he pays for, and since he has to pay for the light before he obtains it, he does not incur any liabilities in this respect.

TRANSFORMING STATIONS AND APPARATUS.—The electricity, when it is sent out from the Electricity Works, is usually of a pressure unsuitably high for the consumer's purposes. Very often also, the consumer's electrical apparatus requires to be supplied with electricity of some other commercial variety than that in which it is sent out from the Electricity Works. The commercial names for the leading forms of electricity are

I. Continuous electricity, and
II. Alternating electricity.

This second form may again be sub-divided into

IIa. Polyphase electricity, and
IIb. Single phase electricity.

It is in the form IIa, *i.e.* polyphase electricity, that the energy is usually sent out from the Electricity Works. As sent out from

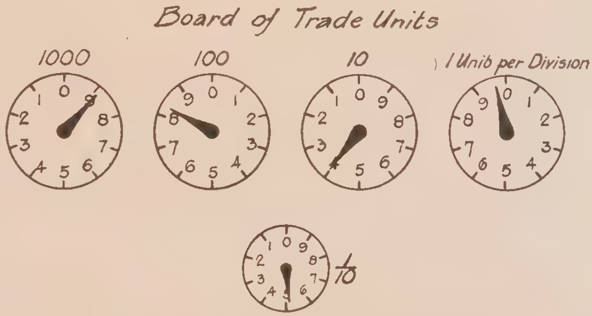


FIG. 6.—Arrangement of Dials on an Electricity Meter.

the Works the electricity is of high pressure. If the consumer requires his electricity in this same form but at lower pressure, the change is effected by interposing a so-called stationary transformer.

Such a piece of apparatus is, in principle, a laminated iron structure on which are wound two coils, one of which, termed the primary, is connected to the high pressure circuit, the other, termed the secondary, being connected to the low pressure circuit, *i.e.* to the circuit on the consumer's premises. Stationary transformers also suffice for obtaining a single phase supply from a polyphase circuit. Thus, when it is required to simply

change the pressure of alternating electricity, a stationary transformer suffices. In this type of apparatus the transformation is effected at an efficiency of some 90 to 98 %, according to the size, periodicity, and pressures.

Very often, however, the required transformation is from the high pressure polyphase electricity supplied from the Electricity Works, into low pressure continuous electricity; in fact, in the majority of cases, the low pressure circuits, whether for lighting or for power, are designed for continuous electricity.

To effect a transformation of energy from any form of alternating electricity into continuous electricity, rotating apparatus is required. The transformation is usually effected on a large scale in apparatus located in so-called sub-stations. The most suitable apparatus for the purpose is a motor generator. The motor receives the electricity to be transformed and converts it into mechanical energy, which serves to drive the electric generator in which it again becomes transformed into electrical energy. This electrical energy is in the continuous form and of the pressure required by the consumer. The transformation is, in the customary sizes, effected with an efficiency of some 85 to 90 %.

There is a device termed a rotary converter which is often put forward for such work. It is, however, as regards adjustability and convenience of operation, distinctly inferior to the motor generator. It has slightly higher efficiency, and is also cheaper, but its superiority in these respects is more than offset by its inferior operating characteristics. The same verdict applies to the so-called motor converter which is a compromise between the motor generator and the rotary converter.

Electric Motors.—The most suitable type of electric motor can, in any particular case, only be determined upon by careful consideration of the work required of it. The two chief classes are

1. Continuous motors.
2. Alternating motors.

1. Continuous Motors.—Where a variable speed is required, continuous motors are preferable, as any desired range of speed may be provided by suitably designed continuous motors. Exceedingly fine speed adjustments may also be obtained with these motors. Continuous motors may be divided into two broad classes:

a. Series wound motors.
b. Shunt wound motors.

Series wound motors are usually employed for work where a high starting torque is desired, and where the motors are started and stopped at frequent intervals. They are almost invariably employed for tramcars and for electric propulsion in general. Series motors are not suitable where constant speed is desired at varying loads, since the speed of the motor decreases greatly with increasing load.

Shunt motors should be supplied for cases where it is desired to obtain constant speed independently of load variations. This speed can be altered to any one of a wide range of values by simple adjustment of the excitation. After the excitation has been once adjusted, the speed remains constant for all loads until the excitation is readjusted for some other desired speed. This process is termed "speed variation by shunt control."

2. Alternating Motors.—These are usually of the polyphase type and have the characteristic that, except for types of complicated construction, they can only be run efficiently at some one particular speed. This restricts their use to a certain extent, but for industrial processes it constitutes a valuable property.

The most hardy form of polyphase motor is that commonly called a squirrel-cage motor, for the reason that the conducting system carried by the rotating member bears some resemblance to a squirrel-cage. In this type of motor there are no moving contacts, and consequently there is a minimum of likelihood of anything getting out of order. On the other hand, this type of motor has but slight starting torque, or when arranged for developing any considerable amount of starting torque it is necessary to consume, during the process of starting, a very large current. The

motor is so hardy as to be absolutely unharmed by these large but temporary currents. On the other hand, these currents interfere with the maintenance of good pressure regulation on the supply mains, and are thus harmful where lights are supplied from the same circuits. If the supply mains are liberally designed, there should be no objection to the use of squirrel-cage motors of not over 5 h.p. capacity, even when required to develop, at starting, one-third of their full load torque. Much larger squirrel-cage motors may also be permitted, provided they may be started up without load.

When high starting torque with only moderate current consumption is required, polyphase motors of the slip ring type should be employed instead of squirrel-cage motors. With these slip ring alternating motors, equally good starting torque may be obtained as with continuous motors. With the slip ring type it is also practicable, by the use of an external rheostat, to obtain any desired speed, but only at very low efficiency.

There is another class of alternating motor termed the single phase motor. When a variable speed motor is required on premises where the supply is alternating electricity, a single phase commutator motor should be employed. For work where the speed may vary with the load, such motors are available up to several hundred h.p. capacity, but the types of single phase commutator motor suitable for constant speed with varying load, are only satisfactory in very small sizes. All single phase motors are very large and expensive for their output, and they have relatively low efficiency as compared with continuous motors and polyphase alternating motors.

Series wound single phase commutator motors have for several years been employed for traction, but with indifferent results. The chief drawback is that the equipment is far heavier and more expensive than the equivalent equipment with continuous motors.

H. M. H.

Electrolysis, Purification by.—Purification of water or sewage by *direct* electrolysis has been a failure in practice, mainly because a great part of the liquid passed nearly or quite unaltered between the electrodes. In an indirect process, the Hermite, sea water is electrolysed and added to sewage or used for flushing. The fluid acted in most cases as a solution of hypochlorous acid (see "Chloride of Lime"), and its standard strength was 0·05 % of available chlorine. A cause of failure was that the solid lumps in raw sewage were so difficult of penetration. By the electrolysis of brine containing 2 % or 3 % of NaCl, Woolf prepared "Electrozone," which was employed on the effluent at Maidenhead, but afterwards abandoned; it was later used with hygienic success at Havana, Cuba. Difficulties have been the expenditure of power in proportion to the result and the rapid spoiling of the solutions. A stronger liquid is now manufactured from brine by the "Oxychlorides" Company in a special electrolyser which claims several economic advantages, while by certain additions the properties of the fluid are made more lasting. Its use is still being tried at the Guildford Sewage Works, and has recently been examined there by the writer, and also by the Sewage Commission. Raw sewages from this and other places, and effluents from septic tanks and primary, secondary, and tertiary filters, were treated with the solution under varying conditions to ascertain its efficiency as dealing with putrefactive and pathogenic organisms and with suspended matter which might cause subsequent trouble. The experiments showed, in common with the results of other investigators, that the germicidal power of these solutions was exerted almost immediately, and was greater than the chemical measure of their "available chlorine" content, but that the latter was very rapidly reduced by organic matters present, whereas it was advisable for a small margin to be left for a slightly longer continued action, in which the active chlorine would disappear. For efficiency the chlorous solution is therefore applied quantitatively,

and for economy the organic matter should be previously reduced by ordinary sewage treatment, the electrolysed solution being used as a "finisher." In the strong raw sewage at Guildford the total organisms were reduced by 3 parts per 100,000 of available chlorine from several millions to 50,000, by 5 parts to 20, and by 7 parts to 10 per c.c. With 3·7 parts available chlorine the reduction was: *coli* organisms from over one million to none found in 1 c.c.; *enteritidis* spores from over 1,000 to less than 10; total organisms from 23 millions to 240 per c.c. Average weaker sewages gave similar results with less of the solution, and within limits a longer period of treatment also allowed of a lower available chlorine. The sludge was less, and when spread on land remained sweeter than with ordinary chemical treatment. It was found that in these polluted liquids about 60% of the available chlorine was almost at once taken up by the organic matters, while the remainder acted immediately on the bacteria and more slowly on the resistant impurities. In septic tank liquors with 2½ to 4½ parts of available chlorine and 1 to 4 hours contact, an original content of 2½ to 4½ million total organisms, 100,000 to a million *coli*, and 10 to 1,000 *enteritidis* spores per c.c., became 20 to 600 total, with *coli* and *enteritidis* absent from 1, and in most cases from 5 c.c., while the incubation and dissolved oxygen tests were also rendered satisfactory. With good effluents sterility, except as regards a few organisms of the hay-bacillus type, which are useful in the further breaking down of organic matter, was ensured by 5 parts per 100,000 of available chlorine, and removal of *coli* and *enteritidis* by 0·5 or even 0·25 part, in 2 to 4 hours. Mixing and proper time are attained by running through a conduit with baffle plates or cascades; the effluent at the outfall should show a faint blue tint with iodide of potassium and starch. The solution also proved effective against the growth of algæ and fungi in waters, and in the treatment of a tap water for conferva the only chemical alteration was an increase of the chlorine from 2·1 to 2·4 parts Cl per 100,000 and a decrease of the "oxygen consumed." The Royal Commission on Sewage found at Guildford that a small quantity of the liquid rendered septic tank effluents inoffensive, and that "a dose of oxychloride more than sufficient to remove smell and kill *coli* did not prejudice the purifying ability of filters." The above results as to conditions for practical sterilisation have been since confirmed by Phelps and Carpenter at the Massachusetts Station,[1] who consider that electrolytic chlorine is cheaper and probably more efficient than chloride of lime, and by Kellerman and others for the U.S. Department of Agriculture.[2] (*See also* "Ozone, Purification of Water by.") S. R.

Enteric Fever.—(*See* "Typhoid Fever.")

Estimating (General Engineering).—The methods by which the cost of engineering work may be arrived at vary somewhat with the class of the job, and also with the purpose of the estimate. If, for instance, a municipal engineer wishes to count the cost of a proposed undertaking, which, if proceeded with, will be executed by a contractor, he will chiefly be concerned with the price to be paid, not with the actual cost of the work to the contractor or manufacturer. If, on the other hand, the work is to be carried out by his own staff, he will require to ascertain the probable cost of production. In the first case the engineer will be in the position of a buyer, and will, therefore, acquaint himself with the market values of the various classes of material and workmanship contained in his scheme. Supposing, however, that he intends to carry out the work himself, he is then somewhat in the position of a contractor, except that he will not be embarrassed with the difficult question of profit. The latter depends upon the nature of the work, the state of trade, competition, the reputation of the contractor, and other factors. To properly

[1] "Techn. Quarterly," 1906.
[2] Bulletin 115, Oct., 1907.

weigh such considerations requires a knowledge of, and a talent for, business, that can only be gained by experience, coupled with an aptitude which is more or less a gift. From what has been said it will be evident that two principles are involved in an engineering estimate—the technical and the commercial. The technical work consists in calculating the quantity and frequently the weight of the material, and estimating the amount of labour required, whilst the pricing of the material and labour, and the addition of a proper sum for working expenses, contingencies, and profit, constitute the commercial element. The materials employed by engineers are numerous and varied, but the methods used to determine their extent are much the same in all cases, and consist in the practical application of the rules of mensuration. With some materials, such as metals, a further calculation is made to ascertain their weight, whilst with others this is unnecessary, as their price is based upon the cubical contents and sometimes their superficial area. Obviously, many articles will be purchased in a finished state. The estimation of workmanship is far more difficult and needs experience and judgment. Cost sheets of similar jobs, when available, should always be studied, but the information derived therefrom must be applied with discretion, as the conditions may not be the same, especially after a lapse of time. Certain articles of manufacture, castings and forgings for instance, are so regularly and repeatedly produced that a rate, varying with the class of the work, can be charged, which will cover both material and workmanship. In this case it is, of course, only necessary to calculate the weight of the article—whether it is produced on the premises or bought outside. The number of foremen, shop labourers, and others indirectly engaged upon the work, bears a fairly constant relation to the number of craftsmen, so that, except in special jobs requiring extra supervision or assistance, their wages are not directly charged, but added in the form of a percentage, usually upon the skilled labour. Two systems of pricing materials and workmanship are in vogue; the simpler and more usual plan is to charge them at rates which will cover working expenses and include profit, the resulting estimate representing the probable cost to the buyer. The other system is to rate the material at its actual cost to the manufacturer, and to debit each item of workmanship with the wages that it is estimated, will be paid, *plus* a percentage to cover working expenses. In this way, the probable actual cost to the manufacturer or contractor is arrived at, leaving him free to add a sum for contingencies if the work is of a nature to require it, and whatever amount of profit he may desire, or consider advisable. This is certainly a more exact method than the other, and has many advantages; for one thing it enables a close comparison to be made between the estimated and the actual cost of the work. The question of working expenses is a most important one, as in some branches of engineering, *e.g.*, a machine shop, they amount to as much, or even more, than the wages paid to the skilled men. Working or indirect expenses may be said to consist of those items which it is not practicable to charge directly to the customers, such as rent, rates, fuel, wages of unskilled labour, supervision and management, interest on capital, repairs, insurance, and the many other expenses incurred in carrying on the work of an establishment. They may be arrived at by dividing the total expenditure over a given period under three heads, viz., materials charged to jobs, wages ditto, the remainder representing indirect expenses. The ratio that the last will bear to the direct expenditure will vary with the nature of the work carried on, and therefore will not be the same for each department; further, it will alter from time to time, according to the state of trade. The percentage representing indirect expenses might be applied to material, wages, or both. As wages are not liable to such fluctuations as material, and for the reason that many items of indirect expenditure will vary with the number of skilled workmen employed, a

percentage based upon the wages of the latter will generally bear a more constant relation than one upon material, and is in consequence usually to be preferred. This point is, however, largely decided by the nature of the business. As previously mentioned, some departments are more expensive to run than others; to arrive at a correct distribution involves a careful division of the aggregate expenses into those which are special to each department and common to all. If the special expenses are allotted to the departments incurring them, and the common expenses are spread over the departments in proportion to the skilled wages paid in each, a practically correct distribution should be effected.

E. L. B.

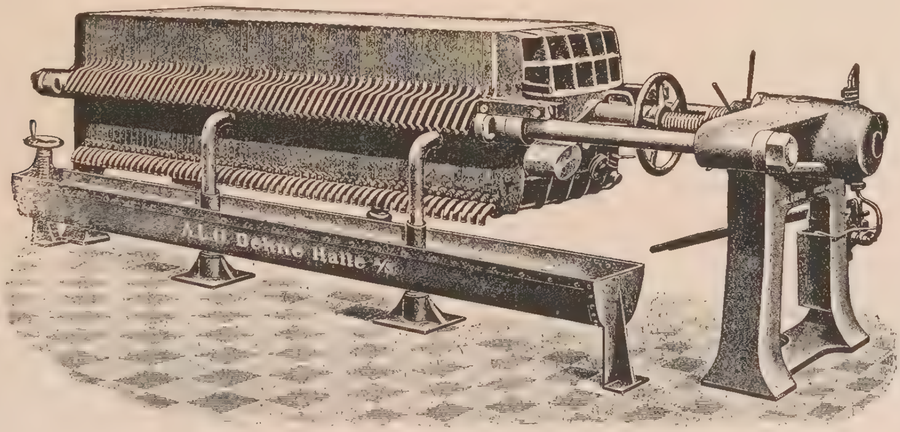
Ferozone, or magnetic ferrous carbon (*see* "INTERNATIONAL PROCESS OF SEWAGE PURIFICATION").—This material is obtained from the same mineral that forms the basis of "polarite" (*see* "POLARITE"), but is treated in a different way. Ferozone is rich in ferrous iron, and alum, calcium, sulphate of magnesia, and rustless magnetic oxide of iron are amongst its constituents. The object of the "ferozone" is to act as a precipitant and to assist in the disinfection and deodorisation of the sewage and sludge.

Ferrometer.—(*See* "CONDER'S SULPHATE OF IRON PROCESS.")

Filtering Head.—(*See* "FILTRATION.")

Filters, Domestic.—Filters may be used in domestic practice for removing visible suspended matter, for arresting microscopic organisms such as bacteria, and for modifying the chemical composition of the water itself. From the sanitary standpoint the effect of a filter on the chemical composition of a natural water is of no practical importance. Apart from injurious metals, such as lead, and from excessive quantities of such salts as calcium carbonate, on which filtration exerts only a trifling effect, it is questionable whether any chemical constituents even of polluted waters in the quantities in which they can occur naturally have any physiological effect at all. There is certainly no evidence whatever that water which has been subjected to such chemical modification as can be produced by a filter is in any respect more wholesome or less dangerous than the same water before it has undergone such chemical treatment. Few domestic filters do more than remove suspended matter. They generally allow the passage of bacteria through the filter-mass into the filtrate. If a water which has been infected even slightly and temporarily is passed through such a filter, some of the infective bacteria will be arrested in the favourable breeding ground provided in the filter pores, and may multiply there for very long periods, causing enormous increase in the extent of infection of any further water which may pass through it, or polluting dangerously a fresh supply of water which before filtration may be quite pure. Accordingly the ordinary chemical filter, whether of carbon (animal or vegetable charcoal, plain, "silicated," or "manganous"), sponge, felt, iron (spongy or magnetic), or equivalent materials must be condemned as able to produce grave danger and wholly incapable of affording any real protection to health. When used for the removal of visible suspended matter any suspicious water passed through them must be treated so as to destroy or remove any disease bacteria which it may contain. The removal of bacteria from water by filters depends on some surface action which is not thoroughly understood. It is not merely a straining such as occurs in the removal of visible suspended matter, for bacteria will be arrested in pores much larger than themselves. Bacteria so arrested may find their way ultimately into the filtered water if the conditions are such as to allow this. This passage of bacteria through the pores is not caused by mere pressure of water, and is probably due to the growth of the bacteria in the pores of the filter under the influence of substances favourable to their development. The extent to which this

growth occurs depends on the nature of the bacteria. Those which are normal inhabitants of water, and, therefore, develop at low temperatures upon substances such as are contained in water, will grow through the pores of a filter, when bacteria which cause disease in man and grow normally at higher temperatures and upon media not found in water may fail to penetrate. Of bacterial filters the Pasteur (Chamberland) is the best known. Laboratory evidence has shown that it arrests any pathogenic bacteria contained in drinking water, and, what is still more important, the filter has been used widely under conditions permitting accurate record of the effect on waterborne disease. Other forms of filter devised for bacterial filtration are the Berkefeld in infusorial earth, the Mallié, and the Doulton. No considerable practical experience is available in regard to the last two. The Berkefeld was the filter supplied to the British troops in the South African war, and experience gained in that campaign, confirmed by a subsequent investigation in the laboratories of Netley Hospital, showed that, contrary to what had sometimes been hoped, it could not give the required protection without precautions and tests that are impossible in domestic use and even in general institutional practice. Wherever possible a filter should be of the "pressure" type and applied direct to the main, the filtrate being collected in a suitable reservoir. The filter is thus kept constantly charged and omissions to fill it avoided. A filter should be chosen of larger initial output than what will be actually drunk, as there is some decrease in output through use, the extent varying with the nature (not necessarily with the bacteriological quality) of the water. W. P.



"Dehne" Sludge Press, by Harzer & Co.

Filter-Presses for Sewage Sludge.—Of the various methods for dealing with sewage sludge, that of forming it under pressure into cakes is among the best. For this purpose filter-presses are used, by which means the greater part of the superabundant moisture is removed. A good type of filter-press consists of a number of strong corrugated iron plates placed vertically, each pierced with a hole in the centre, and having planed margins raised somewhat above the levels of the corrugations. These plates are covered on both sides with filter-cloth, which is fixed around the centre holes. When the plates are tightened one against the other a hollow space is found between each two plates owing to the raised margins. The end plate is not pierced, and the packing of the filter-cloth makes the spaces quite water-tight even under pressure. The liquid to be filtered is forced through the hole in the first plate, filling the

hollow spaces one after the other, and driving the air out by way of an air-valve which is closed as soon as the liquid is seen to rise. As the pressure is continued, the liquid is forced through the filter-cloth, leaving all solid matter in the hollow spaces between the plates. After having passed through the cloth the clear liquid runs down the corrugations, and finds exit through a channel to a trough outside the plates. When the accumulated solids have filled all the hollow spaces (about two-thirds of the space of the whole press), the shutting arrangement is loosened, the plates separated, and the cakes of solids allowed to drop out. These sludge presses can be made with any desired number of plates and the flanges keeping the plates apart can be made of such depth as to provide pressed cakes from 1 in. in thickness upwards. The amount of moisture retained and the character of the effluent depend partly on the nature of the filter-cloth and partly on the pressure used, supplemented by any drying process adopted. The drying can be carried on while the cakes are in the press, before it is opened, by passing either hot air or steam through the cakes by an arrangement of channels, which ensures every part of the cake being thoroughly treated. The cakes thus obtained are quickly made and can be easily handled. The process is as nearly as possible automatic, and is cheap. Filter-presses of this description are in use at the Oldham Sewage Works, where Dr. J. Grossmann's system of extraction of fatty acids from the sludge, and the utilisation of the solid residue as a fertiliser in the form of a dry sterilised odourless powder, containing a high percentage of nitrogen, is being carried out.

Filtration (of water, through sand.)—Filter Beds—Sand Washing—Refilling Beds after Skimming—Length of Service.—Absolutely pure water, as understood by the chemical formula H_2O, does not occur in nature, and, without aëration, is an unpalatable liquid, not beneficial to the human system. The terms "pure" and "impure," as ordinarily employed, are therefore of relative significance, and simply indicate that a water is either fit or unfit for human consumption.

Some form of purification is necessary with the great majority of waters available for public use, as all are liable to contain impurities both in suspension and in solution, consisting of organic as well as inorganic matters. The means adopted for purifying the water supply should be of such a character as to render the water perfectly fit for drinking without previous domestic filtration or boiling. Upland surface water often contains animal and vegetable impurities, and these sometimes cause great trouble by growths and obstructions in mains or pipe-lines, as, for example, arose in the conveyance of the Vyrnwy water from North Wales into Liverpool. Gathering grounds may also be polluted with peat, iron, or even with animal excrement. But it is with river and low-lying lake supplies that the greatest measure of risk lies, such, for instance, as obtains in the case of the rivers Thames and Lea, from which a very large part of the London supply is derived. In all such cases an efficient system of purification, as carried out by the Metropolitan Water Board, is an absolute necessity. Springs afford a safer supply, but their gathering grounds require constant supervision, as surface waters may at times gain direct access to the water by fissures. Underground or deep-well waters are frequently of a high degree of organic purity, but are oftentimes highly charged with mineral impurities in suspension or solution, such as iron, salt, lime, &c., which require removal or reduction by appropriate means before the water can be utilised for public supply.

Attention must be directed to the biological purity of the water as well as to its chemical characteristics, and, since pathogenic impurity may escape both bacteriological and chemical analysis, efficient filtration is the only remaining barrier tending to safeguard the consumer. But even the most careful filtration

cannot always be regarded as an absolute safeguard, hence it is usually wiser to abandon a polluted source of supply whenever an initially pure water is available at reasonable cost.

Filtration.—The greatest dangers in a public supply is that the water should become a vehicle for the dissemination of diseases such as typhoid and cholera, and the connection between sudden outbreaks of this description and the water supply may be best studied from the official reports of inquiries into the epidemics occurring at Worthing (1893), Maidstone (1897), and Lincoln (1905); also at Hamburg and Altona in 1892. In the latter case the practical advantage of sand filtration was proved to be very marked, for, whilst cholera was rampant in districts supplied with Hamburg unfiltered river water, the population drinking the Altona water, subjected to careful sand filtration, was comparatively free. Enormous reductions in the percentage of bacteria are brought about by sedimentation followed by sand filtration. Sedimentation affords one of the most important natural means of purification, and is carried out upon a large scale in connection with the supply of river water to London, notably at the large settling and storage reservoirs of the East London Waterworks adjoining the Lea at Walthamstow and at the new reservoirs constructed for the purpose of taking in Thames water when the river is high, as recently completed at Staines. Simple sedimentation, if the water be allowed to stand long enough, removes nearly all the suspended impurities, and carries down a large proportion of bacterial life contained in the water, some 50 % of the latter being removed by 12 days' storage. Purification by this process is, however, slow, and the necessary tanks and reservoirs occupy a large amount of space and are costly, but, where efficient sedimentation is carried out and the water subsequently passed through sand filters in the best condition, the number of microbes in the filtrate is found to be reduced by as much as from 97 to 99 %. Some of the principal factors affecting the reduction of bacteria in a water supply are: (*a*) the length of time for sedimentation given to the raw unfiltered water; (*b*), the fineness of sand and thickness of bed through which it is filtered; (*c*) the rate of filtration through the sand bed; (*d*) the cleansing of the bed, the renewal of sand, and the general care and watchfulness of the attendants in carrying on the process.

Filter Beds.—The most general method of purification in England, where large quantities of water have to be dealt with, is that of slow filtration through sand. The various filtration works for the supply of London with water from the Thames and Lea are among the largest and most efficient works of the kind in the world.

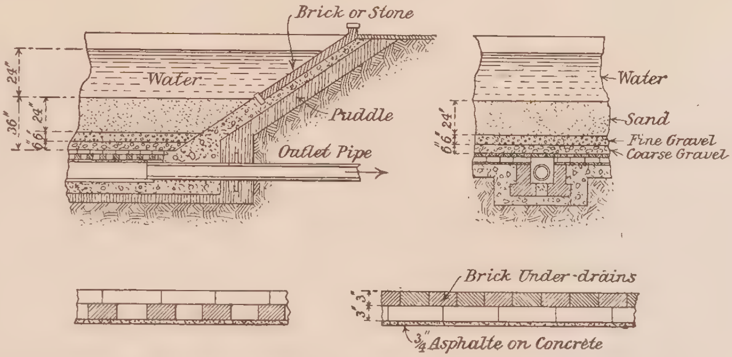


Fig. 1.—Section of Sand-Filter Bed, showing arrangement of Brick Under-drains and Graduated Layers of Filtering Materials.

A "filter bed" is formed by constructing a large shallow tank or reservoir, about 8 ft. deep, usually by excavating partly in the ground and part embanking, and building the walls of brickwork or concrete made water tight with a rendering of cement mortar or a lining of bituminous sheeting overlaid with $4\frac{1}{2}$ in. brickwork, or with concrete. The floor of the filter is given a longitudinal slope towards the outlet, and a cross slope to the

centre, so that the water draining through the sand may run to a common outlet. In filling in the materials into the filter bed, the object to be kept in view is to secure an open porous under-layer, and to this end the first material laid in is of the nature of large stones or sea-beach having a large longitudinal open-jointed collecting drain running through the centre of the floor of the bed with small laterals or branch collecting pipes crossing the bed at intervals of from 3 ft. to 6 ft. The means of collection from the bottom of the bed should be as uniform as possible, so as to secure an equal rate of filtration throughout. One method (Fig. 1) is to form the collecting channels with a 3-in. layer of bricks laid on an asphalte bottom, and overlaid

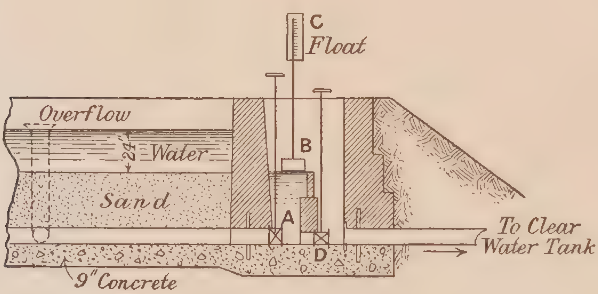


FIG. 2.—Section of Outlet Chamber to Filter, showing Regulation of Water Head.

with another course of bricks placed close together to form a roof over the channels, to carry the gravel and sand which is then laid in. The bricks so used should be of a good, hard, durable quality, not liable to pulverise and break down, otherwise settlements will be caused in the sand, the underdrains become blocked, and unequal filtration or leakage will take place through the sand. The filters should contain a layer not less than about 2 ft. thick of good, sharp, clean sand, consisting as near as possible of pure silica.

It is necessary that means should be provided for the regulation of the rate of filtration and the measurement of the supply to each filter, so that the proper amount of "head" of water may be maintained on the sand. The depth of water on the bed is generally put at about 2 ft., and the rate of filtration should not exceed from 4 in. to 6 in. vertical drop per hour—equivalent to from 18·75 gallons to 28·125 gallons per square yard of surface per hour. A rate of about 2 gallons per square foot per hour is generally allowed in this country, but a good deal will depend upon the condition of the water. When a filter has been drawn down it should be partly refilled from below with filtered water until the sand is covered, and for this purpose advantage may oftentimes be taken of the "head" available from an adjoining filter. The unfiltered water may then be delivered into the filter, and the surface of the sand will not be disturbed. With the same object in view, means should also be provided at the inlet to break the flow of the incoming water by providing a water cushion for the water to fall upon and pass thence quietly on to the filter.

The surface of a sand filter requires cleaning at intervals varying from about 10 days to 4 or 5 weeks, according to the quality of the water. This is done by skimming off about ¼ in. to ½ in. of the surface of the sand with wide flat shovels, placing the same in heaps on the filter for removal to a sand-washing floor. The sand so removed is not usually immediately replaced, but remains until a number of such skimmings have reduced the total thickness on the beds to from 12 in. to 18 in. The thickness is then made up to the original level with the washed sand, which is well mixed with that already on the filter bed. Sometimes the top layer of sand remaining on the bed after the last skimming is removed before putting on the clean sand, and afterwards put on the top of the latter layer. The first water from a filter after cleaning will not, as a rule, be satisfactory for use, unless the filter has been refilled from below, and is therefore frequently run to waste. This arises mainly from the fact that the bulk of the work of filtration is done in the thin film of sand on the surface of the filter, which, after a very few days' use, becomes coated with a fine

deposit of mud, and a gelatinous vegetable growth sets in, thus forming a coating which proves to be by far the most efficient part of the filter. Once formed, the surface film should not be broken until the filter requires cleaning.

To avoid disturbance of the filtering layers of sand, it is necessary to provide for the free passage of air to and from the bottom of the filter by means of air pipes in the side walls of the filter. The roofing over of filters is not often done in this country, although there are advantages to be derived therefrom in the prevention of frost, and the exclusion of direct sunlight, which gives rise to the evolution of gas from the top layer of sand, and causes patches of the surface film to rise and float on the water, thus leaving bare places on the filter through which the water filters more rapidly than on the adjoining surfaces. The area of filters required for any given population may readily be calculated from the permissible rate of filtration already named, allowing a supply at the rate of from 25 to 30 gallons per head, and adding to the area so arrived at an additional area of about one-fourth of that quantity. This additional unit of surface is required so that any corresponding section of the total area may be thrown out of use for cleansing purposes without interrupting the continuance of the supply. For a supply of 1,000,000 gallons per day an area of at least 2,800 sq. yds. of beds would be required, filtering at the rate of 450 gallons per square yard per 24 hours, on the assumption that this rate of filtration could be regularly maintained. As the filters become "ripe," however, the rate of filtration decreases, and the quality of the effluent increases. Sand filtration does not, of course, entirely prevent the passage of bacteria through the sand, and attempts have been made to produce a perfect artificial filter, so that the passage of bacteria and their spores may be entirely prevented by passing the water under pressure through materials having capillary passages sufficiently fine to attain this object. Filters of this type are the Pasteur-Chamberland filter, using biscuit porcelain as a filtering medium, and the Berkefeld filter, in which baked infusorial earth is employed. If properly attended to and frequently sterilised these both give satisfactory results for small domestic filtration purposes. A public water supply, however, should be of such a quality as will render domestic filtration quite unnecessary, as it rarely happens that domestic filtration is carried out with sufficient care and attention to yield much advantage to the householder, and in many instances the so-called filtration becomes positively harmful.

Efforts have been made by means of the surface film upon sand to increase the power of sand and other granular materials to arrest bacteria when passing through the pores of such substances at a greater speed than is ordinarily permissible for successful filtration. This has been done by adding coagulants, such as alum, to the water to be filtered. The effect is to quickly produce a gelatinous substance between the particles of the filtering material.

The sand used for filters should be as nearly as possible pure silica, and be quite clean and sharp. The grade of the sand-grains may be between ·005 in. diameter and ·01 in., or say ·008 in. on the average. Fine grade sands give better effluents than coarse, but the filters naturally choke more readily and call for more frequent cleansing. If, on the other hand, the sand should be too coarse, the impurities penetrate more deeply into the bed, and so entail the removal of a thicker coating at each cleansing. It is often a difficult matter to procure a suitable sand in the locality of filter beds, in which circumstances it becomes necessary to import material from a distance. The present writer has obtained large supplies of suitable sand from Hayle, on the coast of Cornwall. This may be placed in the beds without washing, provided the effluent for the first day or two is run to waste. The sand layer upon the bed may be from 2 ft. to 3 ft. in thickness, to allow a number of skimmings before renewal

with new sand, or with the old sand removed, the same having first been washed.

Sand Washing.—Where plenty of good and suitable sand is readily obtainable, it may not prove economical to wash the sand skimmed off, but it is not often that the purchase of new sand is found to be the cheaper course. Several different types of sand washing plant are in use, such, for example, as that of Hunter & Goodman, as supplied to several of the London waterworks, and Walker's, used at Reading. The main object is to secure thorough cleansing of the sand skimmed from the bed with the expenditure of a minimum of labour and water in carrying out the process. In many cases it is necessary to cleanse the dirty washwater from the sand washing process, and the writer has for many years used settling-tanks, followed by shallow filters, containing about 18 in. of boiler pan-ash, which proves very effective in rendering the water fit for disposal into a water course. Sand washing may cost from 1*s.* to 2*s.* 6*d.* per cubic yard, according to circumstances.

The "filtering head," or the difference of top water level within the bed and that in the "outlet chamber," determines the rate of filtration, and some suitable means should be provided for regulating the work being done. Special appliances for this purpose are supplied by makers of waterworks apparatus, but all such arrangements should be as simple in design as possible, and involve a minimum of attention. The arrangement illustrated in Fig. 2 has been found to be simple in working, and to meet all requirements. The adjustment of the sluice valve *A.* regulates the quantity of water passing over the gauge at *B.*, and the amount or depth of water going over the gauge is recorded at the ground surface by means of a float *C.* The valve *D.* admits of the draining down of the entire filter bed if required.

Refilling Beds after Skimming.—It is a good plan, after cleansing a filter bed, to refil the same with filtered water to the height of about 1 ft., if possible, from the bottom upwards, so as to avoid entrapping air in the interstices of the sand, and also to avoid disturbance of the surface of the bed by the inflow of water from the top. Refilling from below is readily done where the beds are arranged at different levels, as, by a proper adjustment of the inlet and outlet valves, water from the high level beds may be made to head back into those at a lower level.

Length of Service of Filters.—The quality of the water dealt with is the principal factor in determining the length of time a sand filter can be run without skimming. In dealing with river waters and others containing a good deal of suspended matter, and much microscopic animal and vegetable life, the period of service of the filter will be greatly increased by preliminary storage and sedimentation. The London filters run for 30 to 40 days, according to the condition of the water and the amount of previous sedimentation which has taken place. At Berlin and Hamburg the usual period of run before scraping is about 40 days. Filtering operations are oftentimes much interfered with by animal and vegetable growths upon the beds, which, in certain seasons of the year, are sometimes so prolific as to choke the surface in a few days. When the filter is drained down for cleansing, these surface accumulations can often be rolled up off the surface of the sand like a carpet, leaving the clean surface of sand underneath. The writer has experienced much trouble in this connection from an abnormal development of the diatom *asterionella* occurring in a mixed supply of underground water and spring water, the mineral constituents of the former favouring the rapid development of the growth when exposed to warmth and sunlight in open reservoirs or filters. Keeping the underground water separate, and treating it in mechanical filters, effectually removed the trouble from the open storage reservoir and sand filter beds.

Binding materials, such as alum, lime, or sulphate of alumina, are sometimes added to the water to be filtered, with the object of increasing the power of the sand to arrest bacteria,

&c., in passing through the filter. The effect of the coagulant is to produce a glutinous substance upon the filtering media, which acts much in the same way as the film of mud and vegetable growth which forms on the surface of the bed after a few days' use. Coagulants are often added to raw turbid waters, especially in America, to hasten the deposition of fine suspended matter previous to filtration.

Cost of Sand Filters.—This depends largely upon local conditions, the position and accessibility of the site, and facilities for obtaining suitable materials. Under average conditions uncovered sand filters may be expected to cost from £10,000 to £12,000 per acre to construct, and covered filters (seldom used in this country) about £15,000, exclusive of sedimentation basins and other extraneous works.

The working cost of sand filters is also very variable. In London the cost ranges from 3*s.* to 4*s.* 9*d.* per million gallons filtered, including labour, sand washing, and all expenses of cleansing. In smaller works the cost would be proportionately higher.

W. H. M.

Fine Beds.—(*See* "Sewage Disposal.")

Fire Stations and Appliances.—The site to be selected for a fire station should, if it does not stand alone, form the corner of a block. Ready egress and ingress are essential features to be aimed at, and it is desirable that the ingress should lead to a rear courtyard direct, and not through the engine-house proper; a back entrance to the engine-house admitting the engines direct from the courtyard.

Owing to the rapid development of the automobile fire appliances, it is now first of all necessary to decide, before planning a station, whether the appliances are to be horsed or automobile. Unless there be some very cogent reason to the contrary, there should be no difficulty in deciding in favour of the automobile. In the latter case examination pits are necessary under the engine stands, and drip pits 6 in. deep let in the flooring to receive the oil drippings from the engine. In the case of a steam motor engine a shaft connected with a chimney to the roof over the funnel of the fire engine boiler is required to carry off the smoke from the oil fuel when the engine is lighted up on starting out.

Where the appliances are to be horsed, the stables should be in the immediate rear of the engine, with the doors leading from each stall opening outwards to admit of each horse being trained to run up to its allotted position under harness suspended above the pole of the engine.

Steamers, Horsed.—For residential districts the capacity of a steam fire engine should not be less than 350 gallons per minute, delivered through a 1 in. nozzle. For manufacturing districts the pumping capacity of an engine should not be less than 450 gallons per minute, delivered through a $1\frac{1}{4}$ in. nozzle.

The requirements of a district should govern the number and capacity of pumping fire engines. Unless the water supply for the district is such as to dispense with the necessity of a pumping engine, the engines should be of sufficient capacity to deliver the required number of 1 in. jets, which size alone can be considered as being the minimum diameter of efficient fire jets.

Pumping Engines, Automobile.—Most people will consider that the steam engine for an emergency service such as the fire service is the most reliable under all conditions. The uncertainties of the petrol engine as a power for an emergency engine, such as a fire engine, are such as to preclude absolute reliability (which in this case is an essential factor) being obtained where only one engine is available. On the other hand, where an absolutely reliable engine is always in reserve, the petrol pumping engine is decidedly an acquisition to the efficiency of a fire brigade.

There is an important factor to be considered in deciding as between a petrol and a steam mechanically propelled pumping fire engine. The former stands practically ready to move

out on the starting of the engine. In the case of a steam propelled engine it is necessary to have a sufficient head of steam in the boiler to enable it to be started in a given number of seconds. That is to say in brigades where the arrangements do not permit of an immediate turn out on receipt of a "call," it is only necessary to keep a head of steam so regulated that the maximum pressure will be reached during the time which will elapse

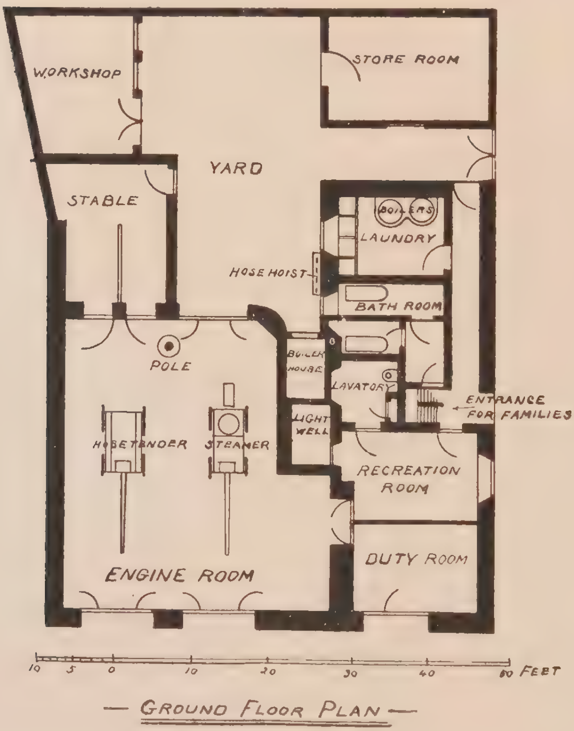


FIG. 1.—District Fire Station, London Road, Edinburgh.

before the men are able to assemble at the fire station to proceed to the fire. If two minutes are required 20 lbs. of steam will suffice, if one minute is required 60 lbs. will suffice, if the engine is to be available for immediate turn out a minimum pressure of 80 lbs. is required.

There are one or two different methods of heating the boiler of the steam motor-engine. The simplest is by inserting a gas ring burner in the fire box. This, however, is the most expensive, for to maintain a head of 60 lbs. of steam will cost about £1 per week. An alternative to the foregoing is to raise steam in a stationary slow combustion boiler to the required head, and connect the latter to the fire engine boiler by flow and return pipes, by means of which the steam is maintained in the fire engine.

From the point of view of cost of maintenance at the fire station, the petrol engine is the more economical, but petrol being so much more costly than the paraffin oil used as fuel for the steam engine, the over-all maintenance is almost equally balanced between both types of engines.

Hose Tender.—The utility of this class of machine consists of the quantity of gear and number of men carried upon it. Whether horsed or mechanically driven, a useful hose tender should carry from 1,200 to 1,800 ft. of hose, 4 stand pipes, 8 branch pipes, nozzles, breechings, hand-pumps, lines, scaling and hook ladders, jumping sheet, lamps, &c.

Horsed Escape.—A machine having almost the same carrying capacity as a hose tender, carrying in addition a fire escape of an average height of 50 ft. which is secured in position by an easily detachable mechanical device.

Chemical Engine.—The chemical engine, or chemical cylinder, as constructed in this country, is an addition to a hose tender or horsed escape in the form of one or two cylinders of from 30 to 60 gallons capacity which are charged by gas generated by a mixture of bicarbonate of soda and nitric acid. Another, and latterly more largely adopted method of supplying gas power to discharge the water from the large cylinders, is to carry compressed air in high pressure cylinders which are connected up to the water cylinders and controlled by valves. The advantage of the compressed air over the chemically produced gas pressure is that as soon as the water cylinder has been discharged on the fire, the latter may be refilled and the compressed air cylinder is again available for

immediate use. A 60-gallon cylinder will discharge an effective jet of water of $\frac{1}{4}$ in. to $\frac{5}{16}$ in. diameter at high pressure to a distance of 40 ft. for eight minutes.

Turntable Ladder.—These machines are built from 60 ft. to 85 ft. in length, and consist of three or four telescopic section ladders. They are built on a mechanically revolving base on a low platform, and may be obtained with either hand power or mechanical extend-

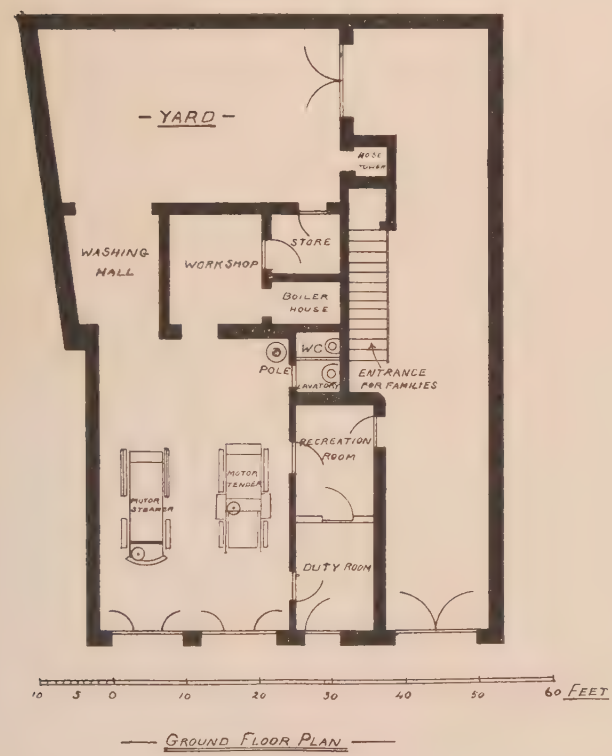


Fig. 2.—District Motor Fire Station, Stockbridge, Edinburgh.

ing gear. The latter is an ingenious engine, which derives its power from compressed air or gas, in cylinders carried on the machine. Four such cylinders are usually carried, and will raise the ladder to its extreme height, an average of several times. These ladders are indispensable to fire brigades in districts where the buildings are above the average height, as they are readily available either for saving life or for use as a water tower.

Nozzles.—There are various forms of nozzles now in use; the most useful nozzles for fires requiring one or two deliveries being those controlled by a shut-off valve on the branch-pipe known as the "London" nozzle, which is provided with one nozzle outlet. Another, and more effective nozzle is the "Multiplex," which has the alternative of three sizes of nozzle, viz., $\frac{1}{4}$ in., $\frac{9}{16}$ in., and $\frac{3}{4}$ in., and a shut-off. This is a useful nozzle, as it provides one of four alternatives which may be obtained without shutting off the water. Shut-off nozzles should only be used on gravitation pressures. Steamers and other pumping engines should use the "Multiplex" "Steamer" nozzle which has three sizes: $\frac{3}{4}$ in., $\frac{7}{8}$ in., and 1 in., without a shut-off. A. P.

Fish Life in Streams.—The well-known fact that fish are greatly affected by the condition of streams has led to the proposal of a "fish test" for effluents, namely, that their quality should be such that fish live healthily in them. Such a definition involves necessarily the absence of poisons and the presence of dissolved oxygen. But while an effluent that kills fish is obviously unhealthy, it does not follow that one where fish will live is therefore a good one. Fresh water species are gross feeders, and are often seen in large numbers at the mouths of sewers, where fæcal matter is visibly floating, being attracted by the insects, crustacea, and fragments of food. They are, in fact, more affected by muddy water and by chemicals from factories than by excreta, which some actually feed on. Perch and trout can live in water holding 3 or 4 c.c. of oxygen in solution out of the average of 7 c.c. per litre, but are soon asphyxiated when only 1·7 c.c. is present. They are not injured by carbonic acid till 10 to 15 % by volume is reached. Fish often die at once when placed in an effluent from chemical precipitation

with lime and ferrous sulphate, on account of deficiency of dissolved oxygen.

Fish as a rule prefer clear streams, and only enter muddy water for food and for breeding purposes. Heavy sediments act injuriously by covering the bed and closing up resting places, and in spawning grounds by interfering with the ova and cutting off the light that is necessary for normal development. But it is pointed out that as salmon traverse the long muddy reaches of the Usk, the Humber, and the upper Severn, the mud and silt of these rivers cannot be inimical to grown fish, or at all events to salmon. A chemical investigation of the sediment in rivers is of great importance. In one case the mud for over 400 yds. below a works discharge was impregnated with naphthalene products, and when disturbed was poisonous to river life, and the writer found the deposit below a paper mill to contain gypsum, chalk, and various pigments, and that below a copper works, to contain this metal; the fish in both were injuriously affected. The effluent from lead mines is similar. In another river where the fish had died, he observed the sediment to be black from ferrous sulphide: the water contained much ferrous iron in solution, which had robbed it of dissolved oxygen, and had modified the aquatic vegetation to anaërobic and semi-aërobic kinds causing offensive odours. Sharp quartz particles and coal washings may cause injury to the eyes, gills, or even the skin of fish, which are sometimes "smothered," through mechanical clogging of the gills by a discharge of sludge when a mill-dam is opened, and in certain cases by storm water. The same effect has occurred from the abundant growth of "distillery fungus," *leptomitus lacteus*, where "burnt" ale, spent lees, and general waste are sent into streams. In America, great destruction of fisheries has been occasioned by the discharge of sawdust. In these cases also, deficient aëration is at work, since all crude effluents, heavily loaded with organic matter, such as the above, and those from starch factories, tanneries, &c., deprive the liquid of free oxygen, hence the chemical figures of dissolved oxygen, and oxygen consumed, should be continually watched in relation to their amounts in the river and the volumes of the two waters mixing. As distinguished from fungus growths, green aquatic vegetation renews the dissolved oxygen, and when not too dense gives a shelter to fish, and, by their feeding on it, is hindered from overgrowth. In certain cases the pollution of estuaries and shores has also done damage to sea fish. At low temperatures, while the solubility of oxygen in water is greater, the amount required to support fish life has been shown to be much less; therefore it is in the summer that special regard must be given to the oxygen content of streams. Other factors, such as disturbance, injury to spawning grounds, and obstructions to access, require consideration, and an increase of the number of birds that feed on fish may render the latter scarcer. Under conditions of proper dilution and aëration, the discharge of sewage or of sewage effluents, is beneficial to fish, since it nourishes crustacea, such as shrimps, and other small life which then form the fishes food. But from polluted rivers it has been shown that the colon bacillus is taken up by fish and multiplies rapidly in their intestinal tract, while its absence was noted in fish from unpolluted waters, and it seems likely that typhoid and other pathogenic organisms may be carried by fish migration.

For further details on the subject see the reports of the Royal Commissions on Salmon Fisheries, 1902, and on Sewage Disposal, 1908, Appendix VI. S. R.

Flash Point.—(*See* "Oil Engines.")

Floating Arms.—Floating arms are employed to draw off the supernatant liquid from precipitation and sedimentation tanks without disturbing the sludge which has been deposited in them. They are also used to empty water-filters. The arm consists of a trunk, generally of iron, and rectangular in section, pivoted at its lower end on the outgoing pipe, and

having at its upper end, which is open, a float, so placed as to hold the mouth of the trunk just below the water level. When the tank is full, the arm is steeply inclined, but, as the liquid is drawn off, it gradually falls, until it rests in a nearly horizontal position on the floor, the level of the mouth meanwhile keeping pace with that of the surface of the liquid. A. J. M.

Flow in Pipes and Conduits.—Laws of Fluid Friction — Hydraulic Gradients — Hydraulic Mean Depth — Velocity in Pipes — Formulæ — Futility of Close Calculations — Discharge — Head for Velocity — Velocity in Sewers. — The velocity of flow in a pipe or conduit depends upon the relation between two opposing forces—the frictional resistances within the pipe, and the power available for overcoming them. Although for practical purposes it is convenient to regard the velocity as being uniform all over the cross-section of the flow, this is very far from being the case. The layer of fluid in contact with the sides is retarded by friction, and moves very slowly: the centre of the stream is subject to no such impedance, and the velocity here is much above the average. This consideration seems to point to the existence of a number of concentric cylinders of fluid, each sliding within the other at a rate which gradually increases as they approach the centre. The actual state of affairs is much more complex. In all but the smallest pipes the contents move in a series of eddies, more or less irregular, but having a general tendency to roll like wheels along the side. A large part of the power to which the motion is due is thus expended in overcoming the viscosity of the fluid.

Laws of Fluid Friction.—Fluid friction is subject to the following laws: (1) The resistance due to friction is not affected by differences in pressure; that is to say, the friction in a water-main at a given velocity is the same whether the water is merely running freely without pressure, or is subject to a pressure of several hundred pounds to the square inch. The same formulæ and tables therefore hold good irrespective of the pressure in the pipes. (2) The frictional resistance is proportional to the area of the wetted surface. (3) At very low velocities the frictional resistance is directly proportional to the speed; but when the velocity is over 6 in. per second the resistance increases approximately as the square of the speed. (4) The frictional resistance is governed by the nature of the surface of the conduit. It was at one time believed that the former was independent of the latter, the fluid being supposed to slide along a thin film held in contact with the surface of the conduit. Subsequent experiments have shown that this is not the case, and that the nature of the material of a pipe or conduit exercises a marked effect on the rate of flow in it. The force which causes the flow in a pipe is usually that of gravity, and is measured by the fall, or the loss of pressure or "head" in a given length of pipe. In some cases it is convenient to express the power expended in overcoming friction as so many pounds per square inch; but in dealing with water-mains or sewers it is more usual (in this country at any rate) to speak of the virtual inclination, or "gradient," of the flow. Thus a pipe 1,000 ft. long, which conveys water from one reservoir to another having its level 10 ft. lower, is said to work under a head of 10 ft., or at a gradient of 1 in 100 (= 10 in 1,000). In America this would be called a grade of 1 %, or 52·8 ft. per mile.

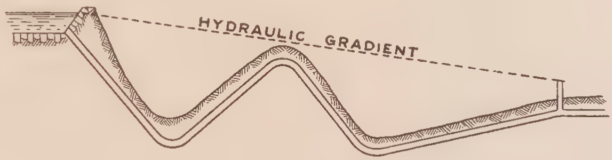


Fig. 1.

Hydraulic Gradient.—The gradient on which the flow in a pipe depends is not necessarily that at which the pipe itself is laid, but is the "hydraulic gradient," that is to say the slope from the water level at the source to that at the point of discharge; or, if the water

is delivered under pressure, to the level to which it would rise in a vertical pipe erected at that point (*see* Fig. 1). Intermediate changes in the inclination of the pipe do not affect the flow, provided that no part of it rises to a height of more than 34 ft. above the hydraulic gradient. It is not desirable, however, that any part of the pipe should rise above the gradient line, as the consequent reduction in pressure is apt to lead to the disengagement of dissolved air, which would accumulate at the upward bends and obstruct the flow. Similar accumulations are apt to take place at all high points, even below the line of the hydraulic gradient. Suitable automatic valves should, therefore, be placed at all summits, to prevent the accumulation of air. In the case of a "rising main," the hydraulic gradient will start from the point to which the water would rise in a vertical pipe carried up from the pump.

Fig. 2.

The power which maintains the flow in a conduit is equal to the weight of the fluid multiplied by the fall, or loss of head. The resistance to the flow depends on its velocity and on the area of the surface with which the fluid is in contact. The circumference of a circle is shorter than the sides of a square of equal area. The frictional resistance in a round conduit will therefore be less than that in a square one, having the same cross-sectional area, and the former will have a higher velocity than the latter with the same loss of head. For a like reason the velocity in a large pipe will be greater than that in a small one.

Hydraulic Mean Depth.—If the circumference of a pipe were straightened out, as in Fig. 2, to form one side of a rectangle having the same area as the pipe, the depth of this rectangle would be equal to one-quarter the diameter of the pipe. This depth is called the "hydraulic mean depth" (h.m.d.)—sometimes, less appropriately, the "hydraulic radius." The hydraulic mean depth of any cross-section may be obtained by dividing the area of flow by the "wetted perimeter," and the velocity in any such cross-section will be equal to that in the circular pipe having the same h.m.d. and hydraulic gradient. Tables of pipe velocities may therefore be used to obtain the rate of flow in conduits of any form.

Velocity in Pipes Running Partly Full.—The h.m.d. and velocity in a pipe, such as a sewer, running half full are equal to those in the same pipe running full bore; and with depths greater than half the diameter the rate of flow will be even higher. The maximum velocity (1·14 times that in the full pipe) occurs when the depth of flow is about four-fifths of the diameter, and the maximum discharge (1·08 times that of the full pipe) with a depth of fifteen-sixteenths of the diameter. On the other hand, with depths less than half the diameter the velocity is less than that of the full sewer. Fig. 3 shows the proportional velocities and discharges for a pipe running partly full, those for the full pipe being taken as unity.

Formulæ.—Within the limits of ordinary practice the rate of flow was formerly believed to be proportional to the square root of the product of the hydraulic mean depth and the hydraulic gradient, and the older formulæ were constructed on this basis. The first regular formula was that introduced by Chezy, and was as follows:— $v = c\sqrt{r\,s}$, v being the velocity in feet per second, r the h.m.d. in feet, s the slope, or fall divided by the length, and c a constant to be determined by experiment. Different values for this constant have been obtained by various investigators. Eytelwein fixed it at about 95, and his formula — $v = 95\sqrt{rs}$ —was widely used down to the latter part of the last century.

The rates of flow given by this and similar formulæ are found to be too high in the

case of small pipes, and too low in that of large ones, the velocity as a matter of fact increasing faster than the square root of the hydraulic mean depth. This fact is taken account of in the formulæ now in use, in some of which also the constant increases with the gradient as well as with the h.m.d. The arrangement of some of these formulæ has in course of time been varied from that adopted by their authors, the symbols in particular having been changed by different writers on the subject. In the present article, for the sake of clearness, the same symbols have been used throughout.

Among the better known of the more recent formulæ are the following :—

Weisbach's: $$v = \sqrt{\frac{2g\ d\ s}{\cdot01439 + \frac{\cdot017155}{\sqrt{v}}}}$$

in which g = acceleration due to gravity = 32·2
and d = diameter of pipe in feet = $4r$.

Darcy's: $$v = \sqrt{\frac{2g\ rs}{\cdot0037285\left(1 + \frac{\cdot2296629}{r}\right)}}$$

Neville's: $v = 140\sqrt{rs} - 11\sqrt[3]{rs}.$

Ganguillet and Kutter's:

$$v = \left\{\frac{41\cdot6 + \frac{1\cdot811}{n} + \frac{\cdot00281}{s}}{1 + \left(41\cdot6 + \frac{\cdot00281}{s}\right)\frac{n}{\sqrt{r}}}\right\}\sqrt{rs}.$$

n being a coefficient for roughness, varying from 0·009 for well-planed timber to 0·050 for torrential streams encumbered with detritus. For pipes of cast-iron or stone-ware n lies between 0·010 and 0·013.

For ordinary use Darcy's formula is simplified by the substitution for the denominator of his fraction of a multiplier c, which ranges from 65 for ½ in. pipes to 113·3 for very large ones, the formula thus taking the same form as Chezy's, viz., $v = c\sqrt{rs}$. Kutter's formula is far too complicated for ordinary use, and several simplifications of it have been proposed which give substantially the same results. One of the most convenient of these is that devised by the late Mr. Santo Crimp and Mr. Bruges, and used by them in the preparation of their admirable "Tables and Diagrams" of velocity and discharge. This formula, in which the cube root of the square the hydraulic mean depth is

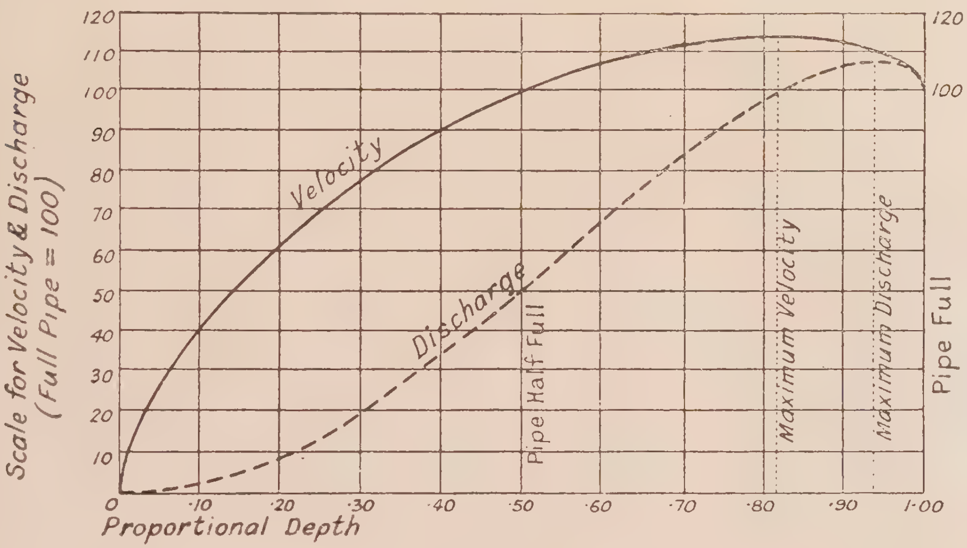


Fig. 3.

substituted for the square root of the latter, is as follows: $v = 124 \sqrt[3]{r^2} \sqrt{s}$. The close agreement between the results of this formula and those obtained from Kutter's, and their very wide divergence from those yielded by some of the older formulæ, will be seen from Fig. 4, which shows the gradient required according to the various formulæ to give a velocity of 3 ft. per second in pipes of different diameters. These formulæ, and the tables which have been worked out from them, deviations in the diameter of a pipe of moderate size may easily affect its carrying capacity to the extent of several cubic feet per minute, while, as Messrs. Crimp and Bruges point out in the preface to their tables, the variations due to the smoothness or roughness of the pipes may range up to 20 %. The effects of corrosion or incrustation will often be still more serious, water-mains having been known to lose more than half their capacity from these causes.

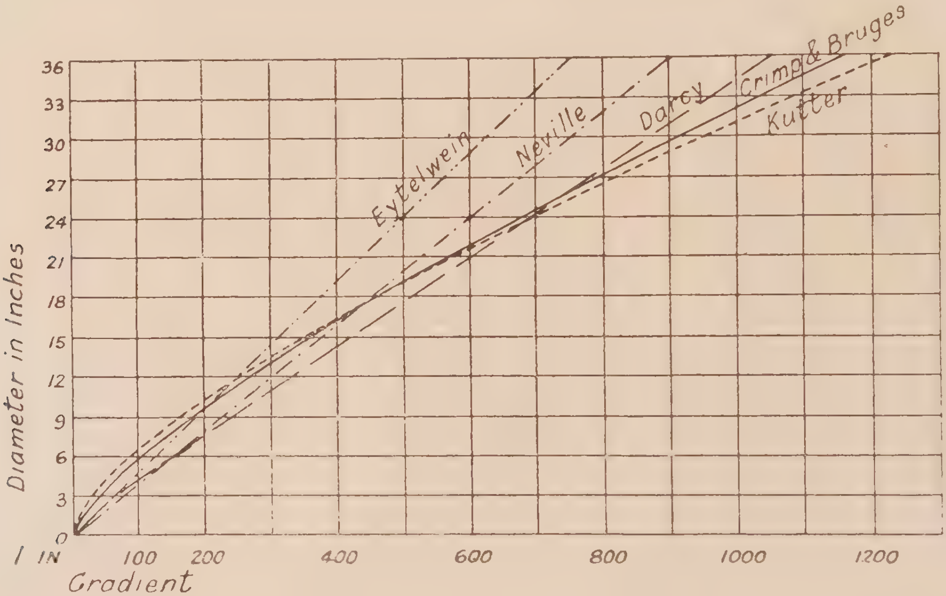


FIG. 4.

hold good, not only for water and sewage, but for liquids and gases of all kinds. It would, however, be inconvenient in practice to have to calculate the pressure of a gas in terms of the height of a column of itself. The pressures of steam and compressed air are therefore expressed in pounds per square inch, and low pressures, such as those of lighting gas, in inches of water.

FUTILITY OF CLOSE CALCULATIONS.—One sometimes sees the carrying capacity of a pipe worked out to many places of decimals. Such minuteness of calculation is quite useless, as it presupposes a degree of accuracy which neither the formula nor the pipes employed are capable of attaining. The allowed

DISCHARGE.—The discharge is arrived at by multiplying the cross-sectional area of the stream by the velocity: thus $Q = a\ v$, where Q = cubic feet per second, a = cross-sectional area in square feet, and v = velocity in feet per second. In circular pipes running full $Q = \frac{\pi}{4} d^2 v$, d being the diameter in feet. Where the discharge is given in cubic feet per minute, it can readily be converted into gallons per day by multiplying by 9,000. A convenient mode of arriving at the approximate discharge in gallons per minute direct from the velocity is to multiply the velocity in yards per minute by the square of the diameter in inches, and divide by 10. The results

thus obtained are about 2 % short of the true ones.

The following tables, which are worked out from Crimp and Bruges' formula, cover most of the cases met with in ordinary practice :—

GRADIENTS REQUIRED FOR GIVEN VELOCITIES.

Velocity : Feet per second. Gradient : 1 in

Diam.	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5
3"	95	75	61	50	42	36	31	27	24	21	19	17	15
4"	140	111	90	74	62	53	46	40	35	31	28	25	22
5"	188	149	121	100	84	71	62	54	47	42	37	33	30
6"	240	190	154	127	107	91	78	68	60	53	47	43	38
7"	295	233	189	156	131	112	96	84	74	65	58	52	47
8"	353	279	226	186	157	134	115	100	88	78	70	63	56
9"	412	326	264	218	183	156	135	117	103	91	81	73	66
10"	475	375	304	251	211	180	155	135	119	105	94	84	76
12"	605	478	388	320	269	229	198	172	151	134	120	107	97
15"	815	644	522	431	362	309	266	232	204	181	161	145	130
18"	1040	821	665	550	462	394	340	296	260	230	205	184	166
21"	1277	1009	817	675	568	484	417	363	319	283	252	226	204
24"	1525	1205	976	807	678	578	498	434	381	338	301	270	244
27"	1785	1411	1143	944	794	676	583	508	446	395	353	317	286
30"	2054	1623	1314	1086	913	778	671	584	513	455	406	364	329
33"	2332	1842	1492	1233	1037	883	762	663	583	516	461	413	373
36"	2619	2069	1676	1385	1164	992	855	745	655	580	517	464	419

The flow in a pipe is seriously impeded by elbows, sharp bends, square junctions or sudden expansions or contractions.

HEAD FOR VELOCITY, &c.—The gradient given in the tables for any velocity is that which will maintain the velocity stated, and does not take account of the head required to generate that velocity in the first place, nor (in the case of a pipe from a reservoir) of the head expended in overcoming the resistance of the entrance to the pipe. In long water-mains the head needed for these purposes may generally be disregarded, but with a short, steep sewer that required to generate the tabled velocity will often be so great that the velocity in question can never be attained in the length of the sewer.

LIMITS OF VELOCITY.—It has been said that the velocity in a water-main should be between 2 and $4\frac{1}{2}$ ft. per second ; and occasionally 3 ft. per second is mentioned as the limit which ought not to be exceeded. The question of velocity is not, however, one to be settled by

DISCHARGES WITH GIVEN VELOCITIES.

Velocity : Feet per second. Discharge : Cubic feet per minute.

Diam.	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5
3"	5·89	6·63	7·36	8·10	8·84	9·57	10·3	11·0	11·8	12·5	13·3	14·0	14·7
4"	10·5	11·8	13·1	14·4	15·7	17·0	18·4	19·7	21·0	22·3	23·6	24·9	26·2
5"	16·4	18·4	20·4	22·5	24·5	26·6	28·6	30·7	32·7	34·8	36·8	38·9	40·9
6"	23·6	26·5	29·4	32·4	35·3	38·3	41·2	44·2	47·1	50·1	53·0	56·0	58·9
7"	32·1	36·1	40·1	44·1	48·1	52·1	56·1	60·1	64·1	68·2	72·2	76·2	80·2
8"	41·9	47·1	52·4	57·6	62·8	68·1	73·3	78·5	83·8	89·0	94·2	99·5	105
9"	53·0	59·6	66·3	72·9	79·5	86·1	92·8	99·4	106	113	119	126	133
10"	65·4	73·6	81·8	90·0	98·2	106	115	123	131	139	147	155	164
12"	94·2	106	118	130	141	153	165	177	189	200	212	224	236
15"	147	166	184	202	221	239	258	276	295	313	331	350	368
18"	212	239	265	292	318	345	371	398	424	451	477	504	530
21"	289	325	361	397	433	469	505	541	577	613	650	686	722
24"	377	424	471	518	565	613	660	707	754	801	848	895	942
27"	477	537	596	656	716	775	835	895	954	1014	1074	1133	1193
30"	589	663	736	810	884	957	1031	1104	1178	1252	1325	1399	1473
33"	713	802	891	980	1069	1158	1247	1336	1425	1515	1604	1693	1782
36"	848	954	1066	1166	1272	1378	1484	1590	1696	1802	1909	2015	2121

any hard and fast rule, as the best rate to adopt is different in nearly every case. For a rising main, for instance, there is a certain size at which the interest on the cost of the pipe, plus the annual expense of pumping, is a minimum. With a smaller pipe the saving in initial cost is more than wiped out by the increased expense of pumping; while with a larger one the saving in pumping will not suffice to pay the interest on the additional cost of the pipe.

Proportional Velocities and Discharges in Pipes running partly full, those for full Pipes being taken as Unity.

Proportional Depth	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·60	·70	·75	·80	·90
Velocity	·257	·401	·517	·615	·701	·776	·843	·902	·954	1·00	1·07	1·12	1·13	1·14	1·12
Discharge	·005	·021	·049	·088	·137	·196	·263	·337	·416	·500	·672	·837	·912	·977	1·07

Velocity in Sewers.—With sewers another set of considerations comes into play, namely, the necessity for maintaining such velocities in them as will prevent the formation of deposits. Du Buat and others have made careful observations of the speed required to keep various substances in motion, and to shift them again when they come to rest. Based on these observations, certain rules have been laid down as to the rates of flow which should be maintained in sewers and drains. For 4-in. and 6-in. pipes a velocity of 3 ft. per second is desirable, and for 9-in. and 12-in. sewers $2\frac{1}{2}$ ft.; while for still larger diameters 2 ft. per second is regarded as sufficient. For this reason, and because of their greater hydraulic mean depths, large sewers may be laid with gradients very much flatter than are permissible with smaller pipes. From this fact a tendency has arisen, in cases where fall is scanty, to employ larger sewers than are called for by the flow, for the sake of the flatter gradients at which it is assumed that they may be laid. The advantage thus sought is wholly illusory, since the actual velocity in a sewer at any gradient depends, not on the size of the pipe, but on the h.m.d. of the stream flowing in it; and, for any given flow, the larger the pipe, the less, as a rule, will be the h.m.d., and consequently the less the velocity. In arriving at the velocity, therefore, the depth of flow must be taken into account. Messrs. Crimp and Bruges' tables, already referred to, include one giving the proportional h.m.d., velocity, and discharge, for depths of flow corresponding to every $\frac{1}{100}$ of the diameter. To take a concrete example: a 4-in. pipe at a gradient of 1 in 160, running half full, will carry 4·9 cu. ft. per minute (44,100 gallons per day) with a velocity of 1·87 ft. per second. In larger pipes, laid at the same gradient, the depth and velocity will be as follows:—

6″ pipe, depth $1\frac{2}{3}$″, velocity 1·82 ft. per sec.
9″ ,, ,, $1\frac{1}{2}$″, ,, 1·75 ,, ,,
12″ ,, ,, $1\frac{1}{3}$″, ,, 1·68 ,, ,,

A 12-in. sewer would not infrequently be used in such a case, and a 4-in. pipe at a gradient of 1 in 160 would be regarded as out of the question; yet the larger pipe would give a velocity only nine-tenths of that which would be attained in the smaller one. The rate of flow in a sewer is in fact governed by its gradient and by the quantity of sewage flowing in it, and only to a much less extent by its diameter; and, so far as the velocity is affected by the latter, it is almost invariably greater in a small pipe than in a larger one.

For various reasons, such as the necessity for providing for storm-water or for a future increase of population, a sewer has often to be made much larger than would suffice for the ordinary dry weather flow; and instances are by no means uncommon in which the depth of flow does not ordinarily exceed one-tenth of the diameter. In such a case the velocity will be only two-fifths of that of the full pipe, and, unless the gradient is exceptionally steep, will be far short of what has generally been supposed to be necessary. With flows at the rate of 1,800 gallons per day or under, and gradients flatter than 1 in 20, $1\frac{1}{2}$ ft. per second is the highest velocity which can be attained, and this only in a 4-in. pipe; and a 12-in. sewer at 1 in 100 will have a rate of flow of 2 ft. per second only when carrying 46,000 gallons per day or more. There are thousands of sewers all over the country in which the flow is utterly inadequate to maintain the velocities which are generally regarded as essential, and which, nevertheless, give perfectly satisfactory results. This apparent discrepancy between the indications obtained by experiment and the results of practical experience is due to a variety of causes, among which may be mentioned the local increase of velocity which takes place wherever the waterway is narrowed by an obstruction, and which either moves the latter bodily onward or breaks it away piecemeal.

Irregularities in the laying of the pipes, and the intrusion of the jointing material into them, play a much greater part in checking the flow in a sewer and in causing deposits than any reasonable flatness of the gradient. The velocity along the invert of a sewer is stated by Mr. Baldwin Latham to be $\frac{9}{10}$ of the mean velocity. Wherever there is any doubt as to the self-cleansing properties of a sewer, flushing should be resorted to. In most pipe sewers the flow, especially near the head of the sewer, is liable to fall for hours at a time below the minimum which can be depended on to prevent deposit. It will, therefore, be prudent to provide means for flushing in every case. (*See* "FLUSHING.")

MAXIMUM VELOCITY IN SEWERS.—In large sewers, where the depth of flow is considerable, and large quantities of grit are apt to be present, it is usual to limit the velocity to about 4 ft. per second, to avoid excessive scour on the invert. In pipe sewers 6 ft. per second has been mentioned as a maximum: in practice such a speed would only be exceeded on very steep gradients, and with flows much larger than are ordinarily met with. Steep gradients, have also been objected to on the ground that, owing to the consequent shallowness of the flow, solid matter is apt to be left stranded in the pipe. Flows which are insufficient to keep a steep sewer clear cannot, however, be relied on to maintain a self-cleansing velocity in a flat one. A. J. M.

Flushing Cisterns.—(*See* "WASTE PREVENTERS.")

Flushing Drains and Sewers.—Wherever possible drains and sewers should be self-cleansing. This depends partly on their gradients, but chiefly on the amount of care which is taken in laying the pipes and making the joints. For 4-in. and 6-in. drains 3 ft. per second is regarded as a self-cleansing velocity; for 9-in. and 12-in. sewers $2\frac{1}{2}$ ft. per second will suffice; and for larger diameters velocities as low as 2 ft. per second may be used. Where these velocities are not obtained with the ordinary flow flushing should be resorted to. Even when the velocity is sufficient to prevent any actual obstruction,

flushing is still desirable for the removal of the accretions which take place on the sides of the sewer. It is especially necessary where the flow is small, as in the upper lengths of a sewer, or in districts not yet fully built up. In certain cases the provision of means for ample and frequent flushing will admit of the use of gradients of exceptional flatness.

Rainwater is practically useless for flushing purposes, the rainfall being far too uncertain to be depended on. Its admission to the sewers, moreover, necessitates the use of larger pipes than would otherwise be necessary, with a consequently sluggish flow. So far as the drains from houses and public institutions are concerned, the provision of special means for flushing can generally be obviated by placing a bath waste at the head of each principal drain. In sewers also the discharge from an ejector or rising main will often serve to flush a long sewer. Where no such means are available a penstock or valve is sometimes placed in the sewer to head up the sewage for flushing purposes. This plan is objectionable on account of the deposits which take place behind the penstock when the sewage is thus kept stagnant, and, for pipe sewers at any rate, proper flush tanks should be provided. These may be filled with sewage if there is fall enough from the feeding sewer into the one to be flushed, but clean water is preferable. Where the water is obtained from the mains the connections should be trapped, to prevent the return of air from the sewers. The size of the flush tank will depend on the size and gradient of the sewer, the following being the capacities usually employed :—

For a 9-in. sewer	. 300 to	400 gallons	
,, 12 ,, ,,	. 400 ,,	600	,,
,, 15 ,, ,,	. 600 ,,	800	,,
,, 18 ,, ,,	. 800 ,,	1,000	,,

and so on.

The discharge from a flush tank may be effected by hand, but should generally be automatic. For house drains tipping buckets may be used, but where the quantity to be discharged exceeds 100 gallons, a siphon will be required. There are many forms of siphon on the market, all belonging to one or two types. In one, when the tank is full, the water falls over a lip, creating a vacuum in the descending leg. In the other, the air is held back by a deep seal, so that the water in the tank ponds up over the siphon until it stands high enough to force the air through the seal, when the siphon at once discharges full bore. A good siphon will start with a drop-by-drop supply. A. J. M.

Flushing Tanks.—Tanks or cisterns constructed to automatically discharge a certain quantity of water at stated intervals for the purpose of flushing drains or certain sanitary fittings, such as urinals, &c. The discharge of the water is brought about by either a tipper or a siphon, fixed in the tank. The timing of the discharges is arranged by the regulation of the tap through which the tank is filled, or by a clock making electric contact at certain hours and thereby releasing the water. (*See also* "Waste Preventers.")

Footpaths, Construction of. — **General Requirements and Width—Foundation for Footways — Construction — Forms of Footpaths — Materials.**

General Requirements and Width.—To ensure satisfaction with any class of footpath, care must be exercised in the choice of materials. They should be durable, ensure perfect comfort and safety to the pedestrian, be smooth and tough but not slippery, of fine texture and uniform quality throughout, and they should wear evenly and not flake, must not absorb an abnormal quantity of water, but dry quickly after rain, should be pleasant in colour and appearance and allow of easy cleansing. As regards the width of footways, the Local Government Board model bye-laws on new streets suggest that each footpath shall be not less than one-sixth the entire width of the street. In several large provincial towns and London boroughs special regulations are in force, and the following which govern the widths of footpaths in all new

streets in the metropolitan borough of Wandsworth will be of use. "In all roads about to be formed 40 (forty) feet in width, each footpath to be made 8 feet wide. In all roads about to be formed 45 feet or 50 feet in width, each footpath to be made 9 feet wide." As a general rule, roads 54 ft. wide have footpaths 10 ft. 6 ins. wide, and roadways 60 ft. wide have footpaths 12 ft. wide.

Foundations for Footways. — These are usually of three kinds :—

1. Concrete.
2. Ashes or gravel.
3. Hardcore.

Concrete foundations should be used for asphalte pavements and under brick paving. The depth varies from 3 in. to 4 in., but a greater depth should be given if the footway is liable to be broken up for main or service pipes of any kind.

Ashes or gravel foundations are used under flag pavements and sometimes under brick pavements. The material should be clean and dry and have a thickness of 4 in. to 6 in.

Hardcore foundations should be provided under all other pavements, especially tar-macadam and granite paving. The depth varies from 4 in. to 6 in., and in cases where soft clay is found an extra depth should be allowed. A system adopted for the foundation under flag paving in a South London borough is as follows :—

The ground is excavated, where necessary, to a depth of $8\frac{1}{2}$ in. The bottom layer is composed of 3 in. of good clean stone or brick hardcore thoroughly rolled and consolidated. On the top of the hardcore a layer of ashes 3 in. in depth is provided, thoroughly rolled and watered. On the top of the layer of ashes artificial stone paving is laid, having a mortar bed $\frac{1}{2}$ in. in thickness. This method has given very satisfactory results.

Construction.—All footways should be laid with a cross-fall from the back of the footpath to the kerb in towns, &c., and from the kerb to the back of the footpath in the case of country roads. The following extract from the model bye-laws of the Local Government Board on new streets gives useful information :—" He shall construct each footway in such street so as to slope or fall towards the kerb or outer edge at the rate of one half of an inch for every foot in width, if the footway be not paved, flagged or asphalted; and at the rate of not less than a quarter of an inch and not more than one half of an inch in every foot in width if the footway be paved, flagged or asphalted."

The Municipal Engineers' Specification gives the following cross-falls :—

$\frac{1}{8}$ in. per foot of width	for asphalte.
$\frac{1}{4}$,, ,, ,,	,, flags (natural and artificial). ,, concrete *in situ*. ,, tar matrix.
$\frac{3}{8}$,, ,, ,,	,, cement matrix. ,, bricks, macadam.

The cross-fall should be allowed in the foundation, the material being laid of uniform thickness. The kerb should be laid first on concrete 6 in. in depth, and show a channel, as suggested by the model bye-laws of the Local Government Board, not less than 3 in. in the shallowest part and not more than 7 in. in the deepest part. It has been found in times of heavy rains that the gully gratings get choked with dead leaves, and much water passes beyond the gully. To prevent this, overflows should be cut in the kerb over each gully about 1 ft. 9 in. to 2 ft. in length. Where carriage entrances occur in the footpath it is usual to construct them in either of the following ways :—

1. The kerb is dropped to within an inch of the channel for the width of the carriage entrances, and the materials (either granite setts, cubes, or blue bricks, &c.) are laid butting against the paving material of the footway.

2. No kerb is laid in front of the carriage entrance, but the paving material is laid up to the channel. Instead of the setts, &c., butting against the flags of the footpath, a return edge kerb 6 in. in width is laid from

the outer kerb to the forecourt fence or wall. In each case the carriage entrance is laid at the same level as the remainder of the footway, except near the edge where it commences to dip to meet the channel. The footway kerb on each side of the carriage entrance is bullnosed.

Forms of Footpaths.—There are two forms of footpaths,

1. Macadam.
2. Paved.

1. Macadam.—The first is used for country roads and villages, but is not to be recommended. The disadvantages are many :—(*a*) The material becomes loose with traffic; (*b*) the paths are muddy in wet weather and very dusty in dry weather; (*c*) they are uneven on the surface, and require constant repairs. This class of footpath is certainly an advance on the bare earth, and is constructed by laying a covering of gravel, engine ashes, or other similar material about 3 or 4 in. deep on the top of the earth, it being then well watered and rolled to a solid formation.

2. Paved Footways.—There are a great many materials used in this form of pavement, among them being :—

Natural stone flags.
Artificial stone flags.
Concrete of various kinds.
Tar paving.
Bricks.
Asphalte.
Various combinations of the above.

Materials.—1. Natural Stone.—There are many quarries from which natural stone may be obtained, but are too numerous to mention in detail in this article. Yorkshire stone is largely used, and is very tough in fibre and wears well if properly selected. Natural stone flags should not be less than 2½ in. in thickness, and should be bedded and jointed with cement mortar. The price of the stone varies in different districts from 5*s*. to 8*s*. 6*d*. per superficial yard, including the foundation. The price in London for 2 in. thick ranges from 4*s*. 3*d*. to 5*s*. 3*d*. per superficial yard, and when laid, from 5*s*. 3*d*. to 6*s*. 3*d*. per superficial yard.

Artificial Stone.—The patent stone flags on the market are too numerous to mention, and only a few will be touched upon. Each stone should be laid to break the joint 6 in. A few makes are Victoria, Aberdeen Adamant, Croft, Imperial, Excelsior, Atlas, Nonslip (hard York) stone. The advantages of this class of paving are: Less cost, even surface, durability, square edges, regular sizes; and the disadvantages are: Tendency to become slippery in wet weather and under the heat of the sun, liable to easily break if bedded unevenly, somewhat dazzling in the sun, when lifted by a pick for repairs are liable to chip. The cost differs considerably, but, as a guide, varies from 4*s*. 6*d*. to 6*s*. 6*d*. per super. yard laid. The cost at the works is as follows :—

Victoria 2 in.	. 3*s*. 6*d*.	per	yard	super.
,, 2½ in.	. 4*s*. 6*d*.	,,	,,	,,
Nonslip (hard York) 2 in.	. 5*s*. 6*d*.	,,	,,	,,
Imperial 2 in.	. 5*s*. 9*d*.	,,	,,	,,

Concrete in situ Paving.—These pavements are generally composed of granite chippings and Portland cement, in the proportion of 4 of chippings to 1 of cement for the bottom layer, and 1 of chippings to 1 of cement for the top layer, having a total depth of about 1½ in. to 2 in. When laid in long lengths this paving cracks very considerably, and wood screeds should be laid down dividing the paving into bays about 4 ft. to 6 ft. in length and the full width of the footpath. Alternate bays are laid and allowed to set before the intermediate bays are filled in. To give a better foothold, these are either grooved or indented by rolling with a grooved or spiked hand-roller. They are difficult to repair, can only be laid after the frosty season, and take considerable time to execute, but, on the other hand, have few joints. Several firms make a speciality of this class of paving, laying it at a fixed price per square yard, and guarantee to maintain it for certain periods of time, and for this reason the work is best left to them to execute.

Tar Paving.—This paving is composed of a bottom layer of tarred granite chippings about 1 in. in diameter rolled down to a thickness of 2 in. This coat is then left open to traffic for a period of about a week. The surface is then swept, and the top layer, consisting of tarred chippings about $\frac{1}{4}$ in. to $\frac{3}{8}$ in. in diameter, is then laid and rolled to a thickness of about 1 in. This is then covered with crushed shell and sand. The cost works out at about 2*s.* 6*d.* per superficial yard.

Bricks.—These are largely used as paving materials, and form very durable surfaces. They are laid on a bed of concrete, varying from 3 in. to 4 in. in thickness in horizontal or diagonal rows. A very effective form of paving is obtained by having a centre portion about 4 ft. wide laid in red bricks and the margins on either side laid with Kentish rag spalls about 4 in. deep, all laid on concrete. The cost of this works out at about 9*s.* per yard super., including foundation, using red sand bricks.

Asphalte.—This form of pavement is laid in exactly the same manner as for roadways, the price being the same. It is slippery and dangerous in wet and hot weather. The foundations for the above pavements have been dealt with in the first part of the article.

F. L. and R. H. B.

Footways.—(*See* "Roads and Streets.")

Forced and Induced Draught.—Mechanical draught, whether "forced" or "induced," enables a higher temperature to be obtained in a furnace, and therefore increases its capacity. It also permits the use of inferior fuels. Several systems of forced draught are in use; one consists of a closed stokehold into which air is forced by means of a fan; thus a greater quantity passes through the furnace than would obtain with natural draught. Under this system the stoker of necessity works in a pressure above that of the atmosphere, and the compartment can only be entered or left through an air lock.

Another plan (Howden's) is to use a closed ashpit and a special fire-door, to both of which air, previously heated, is conveyed, the supply to the ashpit being at a lower pressure than that to the fire-door. The act of opening the fire-door automatically shuts off the supply.

In Meldrum's well-known system the ordinary firing arrangements are retained, but the ashpit is closed. Two bell-mouthed pipes project into the space below the firebars, and in each pipe there is a steam jet, the blast from which forms an air injector and so promotes combustion. This system can be applied to any kind of boiler or the furnace of a refuse-destructor.

The simplest example of induced draught (other than that due to a chimney) is that in use in locomotive and portable engine-boilers —in this case the exhaust steam is discharged into the base of the chimney—the orifice of the blast pipe being usually placed just above the top row of tubes. Mechanically induced draught is effected by employing a suction fan to draw the waste gases from the flue and discharge them into the smoke stack.

Other advantages of mechanical draught are that the chimney need only be high enough to disperse the waste products and to fulfil local requirements. It also admits of regulation, automatically or otherwise, to very varying demands, and is independent of climatic conditions.

Both systems have their advocates. The choice, however, depends partly on local circumstances. (*See* "Boilers, Chimneys.")

E. L. B.

French Drains are trenches or grooves filled with rubble, stone, chalk, or large gravel to allow water to pass away freely. At the back of a retaining wall in a wet soil French drains are put in vertically at intervals of about 10 ft., with a weep hole about 3 in. diameter through the wall at the foot of each drain, to carry off the water and prevent an increase of thrust by hydrostatic

pressure at the back of the wall. In draining land by this means the trenches, about 2 ft. deep, have inclined sides with the bottom filled in with rubble, chalk, or gravel, and covered with straw or brushwood to prevent choking; the soil is then returned to fill the remainder of the depth, say a foot, and lightly rammed to consolidate it.

Frost.—EFFECT ON WATER PIPES AND SANITARY FITTINGS.—Water at a temperature of 32° F., or freezing point, congeals and forms into a solid mass known as ice. At the moment of so doing it expands at great force. It is this action which causes frost-burst in water pipes that have not been properly protected, although the effects are not, as a rule, noticed until the advent of a thaw. Various materials resist frost-burst to different degrees. Lead pipes offer small resistance, but will frequently expand or bulge out sufficiently to prevent fracture. Cast-iron pipes, although stronger, are readily split from end to end. Wrought-iron pipes resist fracture better than either of the foregoing, but are also frequently split.

Hot-water pipes exposed to frost suffer no less than cold-water pipes, and the effect may be much more serious, as the blockage of the pipes by ice may lead to boiler explosions, either by causing excessive steam pressure, or by the sudden admission of cold water to an overheated boiler. Similarly, explosions may be caused by frozen expansion pipes which are gradually blocked by ice formed from condensation in the pipes.

The prevention of frost in water pipes lies in protecting the pipes against frost by placing them in frost-proof positions or by encasing them in non-conductive materials where exposed. Wrapping the pipes in several layers of brown paper pasted down will frequently suffice. Other suitable materials for protection are sawdust, cork chips, hair felt, plaster of Paris, asbestos, slag wool and boiler compositions. The effect of frost on sanitary fittings is less serious than on water pipes, leading merely to the temporary disuse of the fittings affected. In most cases the trouble is caused by leaking taps, the water from which freezes in the waste pipes and gradually blocks them.

W. M.

Fuel.—Combustion is a rapid chemical combination accompanied by the evolution of heat and usually light. The chief supporter of combustion is the oxygen contained in the air, and all bodies which burn in air burn with greater brilliancy in oxygen gas. The quantity of air required for the complete combustion of different fuels varies, but should in each case be correctly apportioned. Insufficient air prevents complete combustion and produces smoke, but an excess of air causes waste of heat as it needlessly lowers the temperature of the flue gases.

If the composition of a fuel is known the heat evolved by its combustion can be calculated. The fuels mostly used are those substances containing large proportions of carbon and hydrogen, such as coal, charcoal, coke, peat and wood, and the liquid and gaseous fuels, the most important of which are the mineral oils and coal gas.

The comparative value of the principal fuels in British thermal units is as follows :—

Fuel.	Evaporative Power from and at 212° F.	British Thermal Units.	Relative Carbon Value.
Carbon	15·0	14,500	1·00
Charcoal (wood) . .	12·4	12,000	·83
Coke (average) . .	13·5	13,000	·89
Welsh Coal (average)	15·3	14,800	1·02
Petroleum (average)	20·7	20,000	1·38
Coal Gas (average)	21·7	21,000	1·45

The ordinary comparative power of Welsh steam coal from 100° F. of feed-water is from 10 to 11 lbs. of water per lb. of coal. In the choice of a coal for pumping purposes the principal point to consider is the selection of that class which, upon the average of a series of tests, evaporates a given quantity of water from a given temperature at the lowest cost. From the steam user's point of view this consideration practically embraces the

whole matter and will determine his decision. A careful commercial test of the various coals that may be under consideration should be made by evaporating a certain known quantity of water in the same boiler by each of the different fuels in turn, taking special care that all the influencing conditions of the test are similar in every case, so that all may be on the same basis as near as practicable. If the fires be not drawn between each test, they should at least be in the same condition as near as possible, the feed-water should be of the same temperature, or proper allowance made, the quantity passed into the boiler should be accurately weighed and the water-level left the same at finish as it stood at the start of the test; the total coal used must also be weighed, and the percentage of ash ascertained. It is also important to note any variation of draught in each case, to observe the amount of smoke produced, differences in stoking, and the nature and amount of the clinker and ash. From such a test it will oftentimes be found that the cheapest coal is by no means the most economical to use. In the coal-mining districts of the Midlands and North of England, and at places where the cost of freightage is light, it is often found economical to use a low class of fuel which may be had at the pits' mouth for a few shillings per ton, but in the South-East of England, where the cost of carriage from the mining districts is heavy, it is as a rule more economical to use the best class of fuel than to pay the heavy carriage rates on a low class material, a large percentage of which will result in ashes. This question of high-class versus low-class fuels is one of great practical importance, and is worthy of the careful consideration of every engineer in the light of the special circumstances of his own case.

Of oil-fuels, a large quantity of that now available in this country comes from the newly opened Beaumont field in Texas. It will evaporate about 15 lbs. of water per pound, has a specific gravity of ·925 at 60° F., a flash point of 185° F. (Abel test), and ignites at 200° F. Its average calorific value is 19,500 British thermal units. Texas and Roumanian cheap oils are now largely used in oil-engines for motive power purposes, in locomotives, and also in stationary boilers.

Gas.—Gas Supply—Manufacture—Distribution — Public Street Lighting — Domestic and Trade Uses—Water Gas.

Gas Supply.—The supply of gas in the United Kingdom is a business carried on as a virtual monopoly, and, in the case of all large undertakings, also under the protection of private Acts of Parliament. There is never an expressed guarantee against competition; but this is implied by the law and rests upon the necessities of the business and the consideration of public convenience, as there cannot advantageously be two sets of gas mains in different ownership in the same street. Some small country gas companies have no special Act, and therefore depend upon maintaining a good understanding with the highway authority, without which they could not lay a main or touch a pipe already buried underneath a public road. Private and public gas Acts give this power, requiring in return certain conditions of the undertakers as regards limitation of profits, sliding scale of selling price and dividends, quality of the gas, and obligation to supply on demand. Gas property is freehold. It is not usual to grant local authorities power to purchase gas undertakings without the consent of the proprietors; although this is sometimes done on proof of expediency being given. The opportunity of obtaining purchasing power ordinarily arises when the company promotes a Bill for fresh and additional powers, such as are calculated to enhance the value of the undertaking. Municipal gas committees succeed to all compatible powers and obligations of the gas company. The general English law of gas supply is contained in the following statutes: The Lighting and Watching Act, 1833; Gasworks Clauses Act, 1847; Towns Improvement Clauses Act, 1847; Sale of Gas Acts, 1859-60; Gas and Water Facilities Act, 1870, Amendment Act, 1873; Gasworks Clauses Act, 1871;

Public Health Act, 1875; Conspiracy and Protection of Property Act, 1875; Public Works Loans Act, 1875; Burghs Gas Supply (Scotland) Act, 1876; Public Health (Ireland) Act, 1878; and Amendments Acts.

Manufacture.—The town gas distributed in the United Kingdom is chiefly composed of the gaseous distillate from bituminous coal, carbonised in closed fire-clay retorts at a temperature of 1,800°—2,000° F. For economical reasons this coal gas is in many places supplemented with a proportion of carburetted or "blue" water gas (see article, "Water Gas"). In good working, about 11,500 cu. ft. of gas should be made from a ton of good coal, the choice of which depends upon geographical and transportation considerations. Towns on or near the eastern and southern seaboard, including London, use chiefly the strongly-coking coals of Northumberland and Durham; with occasional or partial supplies of railway-borne coals from Yorkshire, Derbyshire, Nottinghamshire or North Wales. The quality of gas is expressed in terms of the luminous intensity, in the equivalent number of standard sperm candles of six to the pound, of a flame burning at the rate of 5 cu. ft. per hour, as measured by the photometer under statutory conditions. The gas of the Metropolis and the South of England generally, as well as abroad, wherever the Durham gas coal goes, is rated at from 14 to 16 candle-power. The tendency is in favour of a still lower figure, because this manner of stating the "quality" of town gas is obsolete and does not correspond with modern uses of the commodity. What is classified as 14-candle gas yields on the same basis of consumption, with the incandescent (Auer, or Welsbach) "mantle," 100 candle-light. Gas of higher candle-power with the luminous flame, does not yield a proportionally better light by the incandescent system.

Other saleable products of the distillation of coal for gas-making are coke, tar, and ammoniacal liquor. Sometimes cyanogen salts are also recovered. The gas being the principal product, which must be made in quantity to supply the daily demand, the other products of manufacture are classified as "residuals," or by-products, the market value of which goes to reduce the prime cost of the gas in the holder. The crude gas as it comes from the retorts is laden with the vapours of tar and ammoniacal liquor, which condense in due course, and is charged with the gaseous impurities, sulphuretted hydrogen, ammonia, and carbonic acid. The first is removable by means of oxide of iron or slaked lime; the second by washing with water, with recovery of the ammonia; the third is often left in but is otherwise removable by slaked lime. When oxide of iron is used to absorb the sulphuretted hydrogen, the sulphur is recovered in saleable form. Some sulphur impurity, in other forms than the offensive sulphuretted hydrogen, always remains in coal gas, the quantity ranging from 20 to 50 grains in 100 cu. ft., according to the nature of the coal and the temperature of carbonisation. This sulphur is supposed to exist partly in undetected organic forms without chemical affinity, and consequently irremovable by chemical treatment, and partly (in the case of gas made at a high temperature) as bisulphide of carbon. In whatever forms the sulphur may exist in gas, it burns to sulphurous acid. After purification, and being measured, for administrative reasons, gas is stored in sheet-iron holders over water. Ample storage capacity is a great aid to economy in working. The gas-holders should always be of a capacity equal to one day's (24 hours) maximum output.

Distribution.—The weight of the holder gives the pressure at which the gas is sent out for distribution through the town mains and house services. This weight is lifted, on the manufacturing side, by mechanically driven "exhausters"—so called because they draw off the gas from the retorts, and force it onwards through the purifying apparatus into the holders. The pressure of the holders, on the outlet side, is regulated by "governors." These control the town supply according to the demand, irrespective of any varying

pressure exerted by the holders, which differ in capacity and weight. Sometimes the weight of the holder is insufficient to give the required pressure, when the difficulty can be met by the use of a "booster" fan. Registering pressure indicators should be kept to show the amount of the initial pressure at the works outlet mains, and also at critical localities in the district of supply. The law requires gas mains and services to be kept constantly charged under pressure (Gasworks Clauses Act, 1871, clause 11; Burghs Gas Supply (Scotland) Act, 1876, clause 56). This pressure is not to be less than will balance the weight of a column of water, from midnight to sunset, six-tenths of an inch high, and eight-tenths of an inch high from sunset to midnight. Such a minimum pressure was sufficient at the date of the passing of the Acts, when the sole use of gas was for lighting by means of flat flame or Argand luminous flame burners, which were low pressure appliances, working most satisfactorily at five-tenths pressure. It is inadequate now, when the greater part of gas sold is used for fuel purposes, and by means of incandescent lighting burners, all of which require a pressure of not less than fifteen-tenths at the point of ignition. Therefore the minimum permissible pressure of gas in the street mains night and day should be not less than twenty-tenths, or 2 in. of water; and this pressure should be available all over the district of supply, irrespective of repair operations, &c. Trunk gas mains may be of cast-iron or steel, jointed by means of spigots and sockets, with rope-yarn and lead, or with turned and bored joints. If of steel they may be welded, or of drawn tube. Mains in roadways should be 2 ft. 6 in. deep to the top of the sockets, and are most conveniently laid about 3 ft. from the kerb. Gas mains must not be laid nearer to a water main than 4 ft., and must cross such mains, if necessary, at a right angle (Lighting and Watching Act, 1833). It is the modern practice to supply houses in streets from "service mains," laid at a depth of 12 in. underneath each side pavement, for convenience of access. No main less than 4 in. in diameter should be put underground. In a few large cities street subways for gas and water mains, electric cables, &c., exist under new thoroughfares, but their construction is not generally favoured for old roads. Mains must have a fall of $\frac{1}{140}$ to siphon traps for condensed water. House services are usually of iron, with a few exceptions in favour of lead pipe. A good quality of steam piping, painted, should be used. Gas mains are best tapped on the side, and the service pipe should never be smaller than 1 in. for ordinary frontage lengths. It must be laid with a fall towards the main. Owners or occupiers of any premises situate within 25 yards from a main are entitled to a supply of gas, on paying for all service piping beyond the first 30 ft., and entering into a written contract if required (Gasworks Clauses Act, 1871, clause 11 *et seq.*). The supply must be by meter, if required by the undertakers, who must provide the meter (on demand) according to the Sale of Gas Act, 1860. The register of such meter is *primâ facie* evidence of the quantity of gas consumed, subject to appeal to two justices. Payment for gas may in certain circumstances be demanded in advance, or security may be required. Such security, if in cash deposited, is not an advance payment. Interest is payable on cash deposits. The supply of prepayment meters, stoves, and gas fittings is not compulsory. The amount of gas bills, including meter hire, is recoverable by summary process before justices. Private Acts usually provide against gas stoves, &c., being taken under distress for rent; and also limit the period of error for defective meters to the current, or preceding quarter.

Public Street Lighting.—The supply of gas to public lamps is compulsory on demand at a price settled by agreement when not specified by the special Act. It is usually taken on the basis of the lowest price charged to any private consumer for lighting. The posts, lanterns, and burners are usually the property of the consumer, whether a public authority or any person requiring a street

lamp. Lighting, cleaning, and repairing are ordinarily contracted for with the gas company at intervals of 3 or 5 years. Painting is separate. A schedule of hours of lighting and extinguishing, based on local time, forms part of the contract. "Moonlight schedules" are only favoured for rural districts. The extension of compulsory services to public street lamps is for 50 yards from an existing main. (A main is a pipe supplying two or more consumers.) The supply of gas to public lamps may be on the average meter system, with a meter to every 10 or 12 lamps, but since incandescent lighting has been in vogue this system has generally been abandoned as a needless expense. Street lamps may have governors fixed to them at the expense of either party (Gas Works Clauses Act, 1871, clauses 24 to 27). Anti-vibrators are usually required for incandescent street lamps in busy thoroughfares to economise mantles. Ordinary old-fashioned street lamp-posts and lanterns cannot be satisfactorily converted to the incandescent lighting principle, for which strong, steady posts and wind-proof lanterns are necessary. The capital cost of new posts, lamps, &c., is recouped by the annual saving in gas consumed, which is only 3½ to 4 cu. ft. per hour with Welsbach "C" or Kern No. 4 burners, or Sugg's or Bray's equivalents, as compared with 5 cu. ft. per hour with the old flat flames. With an average yearly lighting period of 4,000 hours the difference quickly mounts up. There is a partial set-off in the cost of mantles, of which from 5 to 12 yearly, or more in roads with heavy traffic may be required. This comparison sets no value on the increased brilliancy of incandescent lighting, which is represented by the proportion 80 to 12 in direct candle-power intensity. A lamp-renewal fund should be maintained by every local gas authority so as to enable the fixtures to be kept up to date. Nothing gives a worse impression than to see an insufficient number of street lamps, ill-kept lanterns, and poor mantle maintenance. Posts in rural roads may be spaced 80 yards apart, and more thickly according to the density of the traffic. Streets over 50 ft. wide between frontages should have double burners, of which one could be extinguished at midnight. Wide boulevards, open places and squares, the processional approaches to public buildings, docks, and large railway stations, are best lighted by high-pressure gas in powerful units. The extra cost of gas compression for this purpose is about 1*d.* per 1,000 cu. ft., and its efficiency is doubled or trebled according to the system adopted. Parliament Square, Parliament Street, and other centres of metropolitan traffic are always kept up to the latest style of good street lighting. There are several mechanical devices available for the simultaneous lighting and extinguishing of public street lamps, some driven by clockwork, others by pneumatic pressure of the gas itself.

Domestic and Trade Uses.—About 50 °/ₒ of the gas sold in towns is consumed for domestic fuel purposes, chiefly cooking and warming of rooms. It is also fast coming into use for heating water circulators in substitution for kitchener boilers. Discounts up to 25 °/ₒ on the normal price, according to quantity, are usually allowed for gas consumed as fuel for trade and industrial purposes, and for gas engines. It is claimed that the cheapest electric light for large business premises is provided by means of private gas power. The consumption of town gas to generate a unit of electricity on the premises is about 30 cu. ft. High temperature furnaces for glass melting, enamelling, or steel brazing and tempering are economically worked with high pressure gas.

Water Gas (Carburetted) is largely manufactured in British towns, especially where the gas coal supply is railway borne, to supplement the bulk coal-gas output. Its comparative cost to the latter in the holder differs in different localities, and therefore it is not everywhere equally favoured. This also largely depends upon the current price of the oil used in the manufacture. Apart from the bare fact of the works cost of this kind of gas, its incidental and consequential recommendations are considerable. It can be installed at a very

important saving of capital, which is a great advantage where increased producing power is required for a heavily-capitalised undertaking. It can be held as a stand-by with far less cost and trouble than reserve coal-gas plant. It is a check upon labour difficulties. When coke is a drug in the market it provides a profitable outlet for the surplus of this residual, and this feature alone in many places justifies the manufacture. Carburetted water gas is not often sent out in this country in a larger proportion than 50 °/₀ of the total, and less than this is the general practice. It is produced by first raising a bed of incandescent coke in a cupola to a high temperature by a blast of air, which is called "the blow," and then passing steam into the glowing mass until its temperature is again lowered, which is called "the run," and so on alternately. The "water gas" resulting from the action of the coke upon the steam is called "blue water gas," and in some systems this product is added directly to the coal gas before purification. From 10 to 15 °/₀ of "blue" water gas, which is non-luminous, but has a high flame temperature, can be added to common coal gas without detriment to the incandescent lighting or the fuel value of the latter. If more water gas is required to be admixed with the coal gas for town distribution it is necessary to "carburet" it—that is, impart to it luminosity and calorific power—by an addition of petroleum oil gas or of some hydrocarbon spirit vapour. In the process of carburetted water gas manufacture the oil is injected into the cupola system and gasified in the current of hot water gas. Where "blue" water gas is added to the coal gas, the mixture can be carburetted afterwards by passing it over or through a vessel containing benzol or petroleum spirit. Blue water gas costs to manufacture about one-third the cost of coal gas; the carburetting brings it up to about the same works cost as coal gas of the same illuminating power. —W. H. Y. W.

Gas Burners.—Modern gas lighting is practically confined to the various patterns and sizes of incandescent mantle burners, of which the original, and still the largest in use, is the Welsbach Incandescent Gas Light Company's "C" type of burner (Fig. 1). Since the expiration of the master patent, the British market has been flooded with cheap and flimsy makes of this burner, but the genuine are marked "aur". These burners take to pieces easily for cleaning, which is a great advantage, as atmospheric dust is the chief source of trouble with all mantle burners. They have no provision for regulating the gas or air supply according to the pressure of the gas, and therefore are only satisfactory when the gas inlet nipple is suited to the quality of the gas supply (because a burner made for 14-candle gas will not properly burn 20-candle gas), and also where the pressure is maintained between thirteen-tenths and twenty-tenths. Where higher pressures prevail, and also where a varying proportion of carburetted water gas may be supplied, some form of gas regulator (as the "Pond" or the "Nico") is desirable, and the fixed primary air holes should be controlled by a thin brass adjustable shutter.

These "C" size burners are the standard for all makes of mantles. They consume from 3½ to 4 cu. ft. of gas per hour, according to the pressure, and yield a light intensity equal in the horizontal direction to that of 60 to 75 candles. As the distribution of their light is mostly horizontal, or upwards, these burners require top reflectors for downward lighting. A valuable improved pattern of upright burner of the type is the "Bray" (Fig. 2) which has several good features, including gas and air adjustment. It is well suited for church or theatre lighting, as it bears turning down without lighting back. Messrs. W. Sugg & Co. also make a variety of upright burners, in a series of sizes, for public street lamps. The most efficient form of upright incandescent burner is the "Kern" (Fig. 3) which yields 20 °/₀ more light than the "C" burner from the same quantity of gas, but is rather more severe upon mantles. It does not require a chimney. No. 4 "Kerns," giving 100 candle-power, are much used for

FIG. 1.

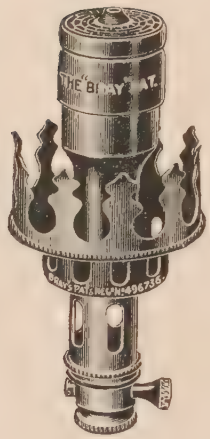


FIG. 2.

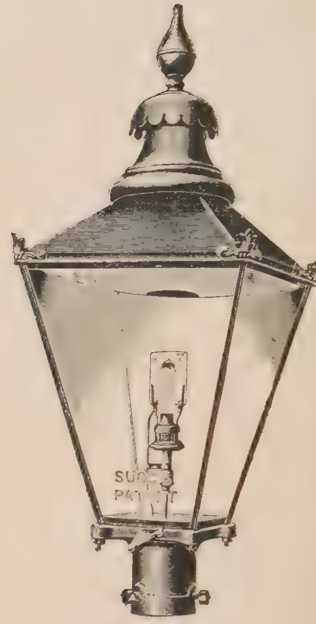


FIG. 3.

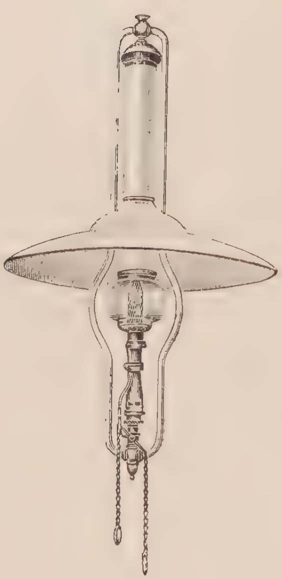


FIG. 4.

FIG 5.

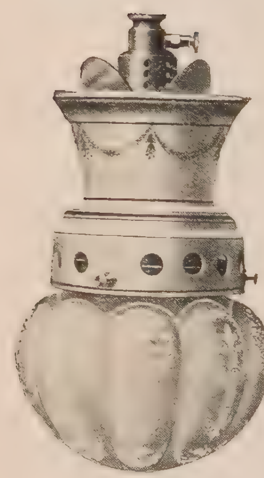


FIG. 6.

public street lamps. They should be governed down to twenty-tenths pressure, for which purpose Carpenter's (South Metropolitan) governor is the best. An excellent pattern of storm-proof lantern, with antivibrator fitting, is shown in Fig. 4. This is suitable for all public street lighting on the ordinary scale, for everything short of very wide, first-class thoroughfares.

Inverted Burners.—Lately incandescent burners of the inverted, or semi-inverted type have seriously challenged the superiority of upright burners, being of at least equal efficiency as illuminants for the quantity of gas consumed, and having a better form of light distribution. Fig. 5 shows a strong pattern of inverted lamp, the "Bland," with protected glass and top reflector for workshop use. Fig. 6 is a "Nico Intense" lamp of the New Inverted Gas Lamp Company, which yields a light of 65 to 70 candle-power for an hourly consumption of $2\frac{1}{3}$ to $2\frac{1}{2}$ cu. ft. of gas. In it the supply of air to the flame is heated, and the outer globe has no bottom orifice. Fig. 7 is a "Vesta Veritas" burner, of Messrs. Falk, Stadelmann & Co., based upon the same principle and yielding similar results. The inner glass is plainly shown. A useful form of inverted burner is shown in Fig. 8, which represents the adjustable lamp of Messrs. G. Bray & Co. This can either be fixed upon an ordinary gas bracket, or pendant arm, in which case the gas and air inlets are upright, and the burner tube only is bent over into the inverted position, or, as shown by the dotted lines, it can be used quite inverted. This fitting is very convenient for shops, and gives little trouble in adjustment.

The inverted form of burner is also adapted in several patterns to outdoor and public street lamps. A windproof lantern arrangement of Messrs. Falk, Stadelmann & Co. for a single mantle is shown in Fig. 9, and a "Vesta Veritas" grouped burner lamp is shown in Fig. 10. These lamps are much favoured for outside shop lighting, as the light is very bright, quite steady, and directed wholly downwards without any shadow. A serviceable lamp of the same type, made by the Welsbach Company, is shown in Fig. 11.

High Pressure Gas Burners.—When a more brilliant source of light is desired than the ordinary incandescent mantle can afford, the effect is producible by artificial intensification of the combustion, which means burning more gas in less space, thus raising the mantle temperature. The simplest way of doing this is by increasing the chimney draught of, say, a large "Welsbach Kern" burner (Fig. 12). The convenience of these "self-intensified" lamps is that they are quite independent and self-sufficing. The illustration is of a 300-candle-power burner for indoor use, as in the lighting of a warehouse, covered goods yard, &c. For outdoor use a Scott-Snell lantern produces the same effect by mechanical action maintained by the heat of combustion.

The most trustworthy means of heightening the brilliancy of incandescent gas light is pressure-increasing mechanism of a positive kind which is applicable to both indoor and outdoor lighting, public or private. There are systems in which the air, or the air and gas supply, are put under higher pressures than the normal, but in general only the gas is so treated. The simplest apparatus of the kind, and highly efficient, is the water-power system of Messrs. James Keith, Blackman & Co. (Fig. 13). The compressor, which occupies little room, can be set up wherever there is a water supply under pressure, and it produces a brilliant mantle action under a gas pressure of 9 in. of water. A useful series of upright and inverted burners is available for this treatment, which costs no more than 1*d.* per 1,000 cu. ft. of gas passed through the apparatus, while the intensity of the light is increased to 30 candles per cubic foot consumed per hour. Another system achieving the same objects is that of Messrs. Sugg & Co., who employ hot air or gas engine power for the purpose, and raise the gas pressure to about 17 in. of water. Triple mantle lanterns so illuminated constitute lighting units of 1,000 candle-power. Another system, the Sale-

FIG. 7.

FIG. 10.

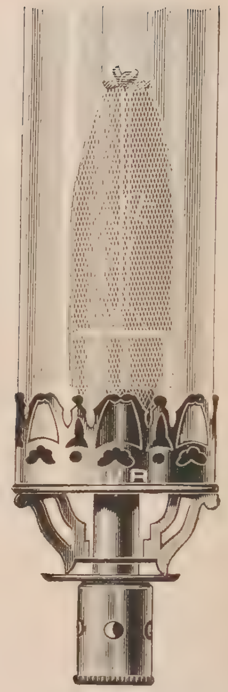


FIG. 12.

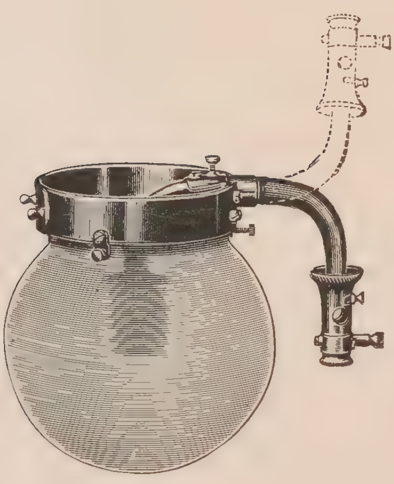


FIG. 8.

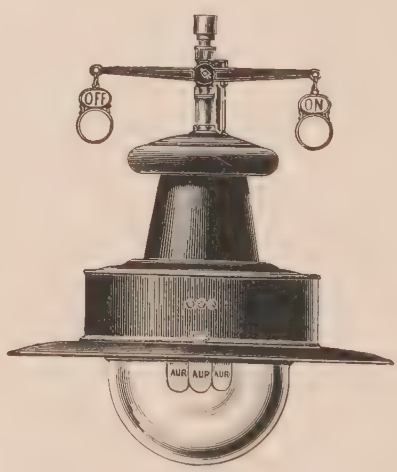


FIG. 11.

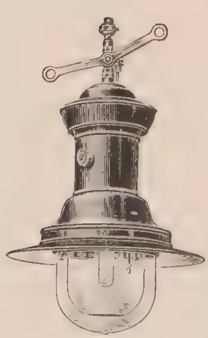


FIG. 9.

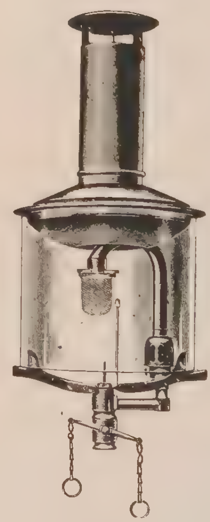


FIG. 15.

Onslow, supplies upright mantles with gas at 54 in. pressure.

The most brilliant gas light of the period is that produced by the inverted system of

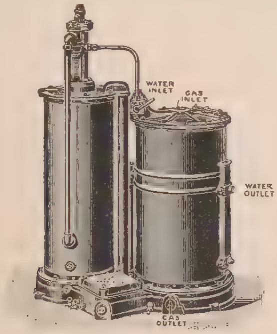


FIG. 13.

Messrs. James Keith, Blackman & Co., worked at a gas pressure of 54 in. of water (4 in. of mercury). The compressor is driven by electric power (Fig. 14). The efficiency of the mantles is about 60 candle-power per cubic foot of gas consumed in the lanterns such as are shown in Fig. 15. The whole equipment is substantially constructed, and the lanterns are durable. A peculiarity of this system is that the mantles are put on in the

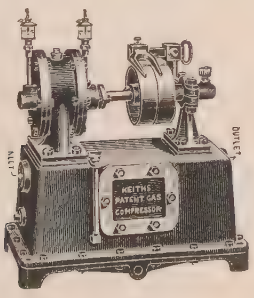


FIG. 14.

soft condition, and shape themselves as the flame is turned on. Various sizes of lamps can be used on the same supply. The light is suitable for large factories, railway yards, wharves, and the most important main city thoroughfares. W. H. Y. W.

Gas and Electric Light Testing.—The testing of gas is generally confined for practical purposes to the estimation of the illuminative value when burnt under defined conditions; to the determination of its heating power and the pressure of the gas in the service. Formerly the quantity of sulphur present in the gas either in the form of sulphuretted hydrogen and other sulphur compounds was considered of importance, but recent legislation has omitted for all practical purposes any restriction on these in the metropolis, and for many years past they have rarely been considered in connection with the supply to the provinces.

In the case of the electric light the essential features of the test are the intensity of light yielded and the current required, expressed in terms of volts and amperes or "Board of Trade units."

The measurement of the light in both cases involves the same photometrical procedure, and is based upon the natural law that the intensity of the light emitted by a given radiant diminishes in inverse ratio to the square of the distance. The following example will illustrate this:—

When it is desired to compare a light with a standard light, a candle for instance, if a translucent paper having a spot of grease in the centre is held between the two lights it is clear that if it is too close to one radiant the light will be too bright on the side of the paper nearest to it, and the light will shine brightly through the greased portion. If the paper is then carried over to the opposed radiant the effect will be transposed, but in its passage from one to the other it will be seen that at some point between them the illumination of each side of the paper will be equal and the grease spot will all but entirely disappear in consequence of the reflected and transmitted light being equal on either side. This neutral point having been found, it is clear that the actual intensities are equal at the given distance from the respective lights. Simple calculation then gives the relative intensities thus: If the distance of the one light be 26 in. from the neutral point and that of the other 44 in., then $\frac{44^2}{26^2} = 2{\cdot}86$, so that the greater light

of the two is 2·86 times that of the weaker. If the latter be known to be, say, equal to 8 candles, *i.e.*, a low-power incandescent electric light, the actual intensity of the greater will be $2{\cdot}86 \times 8 = 22{\cdot}88$ candles. In England the standards of comparison generally employed are either the Parliamentary standard sperm candle, consuming spermaceti at the rate of 126 grains per hour, the sperm consumption being ascertained by weight and the intensity of the light, presumed to vary with the rate of consumption, which must not exceed 126 grains per hour nor fall below 114. In the metropolis the standard employed at the gas-testing stations is that known as Harcourt's 10-candle pentane lamp, which consumes the vapour of pentane (obtained from light petroleum spirit) carried forward to the burner by a current of air. When the flame is at the regulated height the intensity is taken to be equal to 10 standard candles, and no further calculation is needed in that respect. Many alternative standards have been proposed, but beyond certain calibrated electric incandescent lamps used for temporary purposes either of the foregoing are generally employed.

The instruments known as photometers are of many divergent patterns, but the essentials comprise simply supports for the two luminous radiants to be compared and the comparison screen which may be either Bunsen's greased disc above described, or its alternative, the star disc of Leeson, consisting of a thick piece of paper with a perforation in the shape of a star, covered on either side with a thin paper, thus giving opaque surfaces with a translucent centre. This is best for comparing coloured lights of different character. The principle of Rumford's shadow photometer—in which the comparison is made by noting the depth of shadow cast by two vertical rods illuminated by the respective lights, which are moved nearer to or further from the rods until the shadows are of equal depth, or, more truly speaking, the illuminated surfaces are of equal brightness—is employed in the table photometer used in the official testings. The accessory apparatus necessary for testing the illuminating power of coal gas consists in a meter for measuring the rate of consumption, which is generally 5 cu. ft. per hour, a clock with stop action to denote time intervals, a governor to control the steady flow of gas to the testing burner, and a pressure gauge to test the pressures in the different parts of the apparatus. The most complete "bar" photometer comprising the whole of these necessaries is that known as the "Tooley-Street pattern," which gives the steadiest flame to the gas and candles by reason of the freedom from side and top draughts. This was developed as the results of experiments by the writer at the time when the late Professor Tyndal was one of the Gas Referees, the principle involved being the attainment of a large volume of air moving at a slow intensity in a steady upward direction, with the result that an ample supply of air was carried to the burners and the products of combustion freely and steadily removed without top or side draughts.

The candles are carried during the test in a suitable balance, and the quantity of sperm consumed weighed with the candles *in situ*, as great risk is incurred if they are touched, by reason of spilling some of the melted sperm, or otherwise disarranging the rate of consumption. If required, any other standard of comparison may be employed in this photometer, and in the case of testing powerful gas or electric lights these may be placed on suitable supports in a line with the photometer bar, the side of the casing surrounding the gas burner being removed, and the usual scale on the bar being neglected, the respective distances being measured as above indicated; or a special scale may be engraved on the bar, the usual one being for lights 60 in. apart, the readings in that case being made direct instead of having to be calculated as made. It is unnecessary here to enter into details of the method of computing the rate of consumption of the gas and candles, as tables are generally provided with the instruments. An important branch of this work is that introduced by the writer in 1885 under the

term, "Radial Photometry," which denoted the estimation of rays in all directions emitted from a light source. According to the then usual practice only the horizontal rays were taken account of, but the introduction of the inverted and other burners rendered it necessary to estimate in particular those rays falling at varying angles from the horizontal to the perpendicular. For this purpose the radial photometer was made by Messrs. Sugg & Co. to the writer's design.

The support for the illuminant is attached to and shown in front of the raised disc, which slides up and down in its stand. The disc of paper, greased or stained as required, is held in the clamp in front of the lower disc on the right-hand support. Fixed rigidly to the supporting block is the horizontal bar on which slides the comparison standard light. As the inclined bar is moved by any alteration in the position of either block, the taller of the two upright supports slides sideways on the base board, thus always maintaining the full distance of the light from the disc—the arrangements being such that the light may either be directly above the disc or below it—the moving bar indicating and controlling the direction of the rays. Many alternative methods have been proposed, but this is the most complete instrument for the work and is extremely easy to manipulate, even with lanterns of many hundred candle-power intensity.

A convenient portable instrument was designed by Mr. Trotter, and described by him in a paper read before the Institute of Civil Engineers in 1892. It was designed for estimating the intensity of street lighting.

A small standardised electric lamp was fitted at one end of a box. The light from this was received on a reflecting screen of Bristol board mounted on an axis through its upper edge. Above this a simple cardboard screen with a star-shaped hole cut in it was fixed in a horizontal position, so that the observer when looking down on the box would see the reflecting screen through the star-shaped opening. The method of observation consisted in inclining the reflecting screen at different angles, this motion being given by a fine chain wound on a snail cam. A convex lens was used in certain cases to increase the available light from the electric lamp.

The results of the tests of illuminative value are controlled by the quantity of gas consumed in the case of that illuminant, or the strength of the current in the case of electricity. In the case of gas it is not the pressure which is the governing factor, but the chemical or illuminating constituents, or even more important in certain respects, the heating quality, and hence it is that tests for the calorific value of the gas seem likely to displace to a great extent those for mere illuminating value. In the case of electricity the equivalent factor is the voltage, a given volume or amperes being assumed, and the tolerance shown by public authorities to the electrical industry by neglect to establish a severe system of tests and punishments for default in supply, as in the case of gas, has gone not a little way to encourage the growth of the newcomer in the field of luminous energy. For instance, a few percentages different in the photometrical value of gas makes but little difference, but may be punished with heavy and irritating penalties. On the other hand, what happens if the voltage of a supply drops? From tests made by the writer it was found that a 16-candle-power lamp was found to give 15·03 when the current indicated 99·33 volts; but at 96 volts the luminous intensity fell to 10·9 candles, or 27·3, and when it fell to 90 volts the loss of candle-power was exactly 50 per cent. It is therefore clear that the necessity for maintained voltage is of the greatest importance, and too much stress cannot be laid upon it, especially when it is considered that this difference in voltage makes practically little on the quarterly account which is based on the Board of Trade unit, *i.e.* quantity = *amperes*, multiplied by intensity = volts. Thus 1,000 amperes × 1 volt = 1,000 = 1 B.T.U., or 10 amperes × 100 volts = 1 B.T.U., which latter might represent the above case, when a drop of 10 volts out of 100 would mean, with

the sample amperes, 900, or a reduction of 10 % on the bill for a 50 % reduction of light.

It is impossible within the compass of the present article to discuss the questions of Calorimetry; Illuminating Effect, *i.e.*, suitable distance of a light from a surface to be illuminated; Illuminating Value, *i.e.*, intensity of the light which would be required at a foot distance to produce the effect of the given light at its given distance, and other similar points. These should be studied in the text-books devoted to Public Lighting, &c.

The following comparison of cost of illumination by various methods will be of interest. It is abstracted from the writer's work on "Public Lighting."

Electricity at 4*d*. per B.T.U.

Coal gas at 3*s*. per 1,000 cu. ft.

		Cost of producing 1,000 Candles of Light during one hour.	Cost of each Light per hour.
		Pence.	Pence.
Electricity:			
Arc Lamp	450 c.p.	2·2	1·0
,, Frosted Globe		4·0	1·0
,, Opal ,,		6·7	1·0
Incandescent Lamp ..	16·0 ,,	12·5	0·2
Nernst Lamp	65·0 ,,	6·2	0·4
Coal Gas:			
Flat Flame Burners ..	13·0 ,,	13·8	0·18
Argand ,, ..	16·0 ,,	11·2	0·18
Welsbach Mantle ..	60·0 ,,	2·1	0·13
Intensified ,, ..	300·0 ,,	1·2	0·36
Petroleum:			
Kitson's Incandescent	1000·0 ,,	0·8	0·80
Flat Flame	9·5 ,,	9·5	0·09

W. J. D.

Gas Engines.—Heat engines are classified either as internal or external-combustion engines. In the external-combustion engine, heat is generated in a furnace and transmitted through the metal sides of a vessel containing a working fluid, as in the case of the ordinary steam boiler. The water so contained forms the medium by which part of the heat given out by the fuel is transformed into another form of energy and thence passed on for use in the steam-engine. In the internal-combustion engine the heat-producing materials are, at the outset, introduced into the working cylinder uncombined, and there develop the whole of the heat due to combustion, and finally, after having done work in the cylinder, are ejected from it as waste products of combustion. The internal-combustion engine, in thus having the whole heat generated within the cylinder, possesses an important advantage from a thermo-dynamic point of view, seeing that, in external-combustion engines, from 25 to 30 % or more of the total heat produced is lost in the flue gases by radiation and other causes. It has to be borne in mind, however, that the temperature of the cylinder of an internal-combustion engine, of which gas and oil-engines are the best examples, must, for practical reasons, be constantly kept below a certain limit by cooling by means of a water-jacket, and this operation involves a waste even in excess of the chimney waste above-named. Notwithstanding the fact that some 50 % of the total heat generated in the gas-engine cylinder is lost by the water-jacket in this way, experience shows that a higher thermo-dynamic efficiency can be realised in practice in internal-combustion engines than has yet been obtainable in even the best examples of the external-combustion type. With the view of testing the comparative efficiency of large gas-engines worked with Dowson gas and of a good steam-engine and boiler, Professor Witz, of Lille, carried out experiments which yielded the following thermo-dynamic efficiencies[1]:—

	Per cent.
Steam boiler	68 to 76
Gas-producer	70·6
Steam-engine	9·7
Gas-engine	18·0
Steam-engine and boiler ...	7·0
Gas-engine and producer ...	12·7

Dowson gas, obtained from a producer worked with anthracite and coke was used with a 112 I.H.P. single cylinder gas-engine,

[1] "Proc. Inst. C. E.," vol. cix.

and the total consumption of fuel was 1·349 lb. per brake horse-power per hour. The steam-engine under trial was a simple jacketed condensing-engine, with steam at 75 lbs. per square inch generated in a boiler with economiser, and a coal consumption of 2·4 to 2·7 lbs. per brake horse-power hour. Even when a gas-producer is used, the internal-combustion engine shows a considerable efficiency over the steam-engine, and where, as in the case of an oil-engine, the fuel is introduced directly into the cylinder without any external losses, the thermodynamic efficiency of the internal-combustion engine will show a still more favourable comparison with the steam-engine and boiler. In large sized steam-engines higher efficiencies than that assumed above are readily obtainable, but, at the same time, the internal-combustion engine, comparatively speaking, is in its early stages, and further important improvements may be confidently anticipated. The commercial history of the gas-engine dates from 1876, when Dr. Otto introduced the well-known Otto-Crossley engine now so widely used, and applied the cycle of operations originally suggested by Beau de Rochas in 1862. Since 1876, the development of the gas-engine has been more in the improvement of details of construction, increased efficiency, and the use of higher compressions, than in the introduction of any entirely new type of engine. The original Otto gas-engine is a thing of the past, but the present general uniformity in design of gas-engines is a strong indication that the "Otto cycle" is best suited to the commercial gas-engine, although there may be considerable variety in other details.

The Otto cycle engines are explosion engines in which the combustible gaseous mixture is compressed previous to the explosion. The "cycle" consists of five operations, viz. :—

First revolution:
- *Outstroke*, charges the cylinder with gas and air mixture at atmospheric pressure.
- *Instroke*, compresses the charge into a combustion space.

Dead centre, the charge explodes.

Second revolution:
- *Outstroke* (caused by the explosion), expansion of the gases.
- *Instroke* (due to action of fly-wheel), expulsion of the burnt gases from the cylinder.

An impulse to the piston is thus only given every two revolutions (*i.e.* four strokes) of the engine, so that a very heavy fly-wheel is necessary to maintain a constant speed.

In the Otto-Crossley engine, the cylinder, which acts alternately as a motor and a pump, is open-ended and horizontal, and in it works a long trunk piston, the front of which carries the cross-head pin. The cylinder is much longer than the stroke and the piston thus leaves a space, known as the "combustion space," in which the charge is first compressed on the inward stroke as above-named and then burned. In a gas or oil-engine a large amount of stored energy is needed to carry the piston through the negative portion of the cycle as set out above, and for that purpose a large fly-wheel and heavy crank shaft are provided. The valves are four in number—the charge inlet valve, gas inlet valve, igniting valve, and exhaust valve—and are all of the conical seated lift type. The igniting or timing valve determines the time of the explosion. One of the latest improvements in the Crossley engines is due to the introduction of a "scavenging" arrangement by which the exhaust gases remaining in the clearance space are drawn away at the end of the stroke.

Self-starters have become necessary with the introduction of large-sized gas engines, as the starting of these would present considerable difficulty by simply pulling the fly-wheels round as in the smaller engines. Various methods are employed by different makers, but the general idea is to store up a small amount of energy in a separate vessel for the purpose of giving, when re-starting, the first impulse to the piston. In the Westinghouse double-acting engines of large size an automatic compressed air starter is supplied, in which air is stored during the previous run, or is separately compressed and is turned into one cylinder of the engine—the valve functions of which have been altered—until

explosion takes place in the others, when the air is cut off from the starting cylinder, which then resumes its normal functions. Some makers adopt the method of filling the cylinder with gas and then open a connection to a compressed air vessel from which sufficient air under pressure is allowed to flow until a rich explosive mixture is formed at a considerable pressure, which, upon ignition, gives an effective starting impulse. An important practical point to be taken into consideration when adopting large size gas-engines is the avoidance of nuisance caused by their running. This may arise from the noise or smell of the exhaust or from air or ground vibration. The noise from the exhaust may be deadened by conducting it into a "silencing chamber," or pit placed underground containing large pebbles or stones from which an outlet pipe gives relief into the open air. Internal air vibration is often caused by the displacement of a large trunk piston setting up rapid pulsations of air which may be transmitted throughout the passages and other rooms of a large building if such directly communicate with the engine-room. Ground vibration is often set up by the running of large engines, also vibration not only to the walls of the building in which the machinery is situated, but also to those of adjoining properties. Such vibration may be transmitted considerable distances through the ground or communicated to the walls direct where the foundations of the engine abut thereon. Where a material nuisance is alleged to be caused in this way to neighbouring properties, the prevention of such vibrations is often a problem of considerable difficulty. An alteration of the speed of running has in some cases reduced the trouble, possibly due to the altered period of vibration. If such period happens to coincide with that of the building itself, the resulting vibration is likely to become more pronounced. Another remedy applicable in some cases is the bolting down of the engine upon a yielding and springy bed, such as thick cocoanut matting or similar material, sandwiched between two iron plates, the whole being securely held together by strong foundation bolts. In a gas or oil-engine the water-jacket surrounding the working cylinder is required to perform the important function of conveying away the excess of heat due to combustion in the cylinder which cannot under present conditions be converted into useful work. By this means the temperature of the cylinder is kept within suitable limits without which lubrication would be impossible. The heat absorbed by the jacket-water amounts to from 30 to 50 % of the total generated by the combustion of the gases in the cylinder. The circulation of the water takes place in an annular space, of from $\frac{3}{4}$ in. to 2 in., cast around the cylinder, at the underside of which the cool circulating water enters and from the top of which the heated water flows away to the circulating water storage tanks, or as may be arranged. The maximum temperature of the circulating water should not exceed 150° F., and, with water of 60° at the inlet, the quantity required to keep the cylinder cool will be from $4\frac{1}{2}$ to 5 gallons per I.H.P. hour. The circulation is generally arranged through circulating tanks having a capacity of from 20 to 30 gallons per I.H.P. The jacket pipes will be from 1 in. to 2 in. diameter for engines up to about 20 I.H.P., and from 2 in. to 3 in. for inlet with $2\frac{1}{2}$ in. to $3\frac{1}{2}$ in. for the outlet in the case of larger engines. Sometimes several circulating tanks are arranged in series, the pipe connections being arranged so that the water is drawn from the bottom of one tank to the top of the next in the order of the circulation. In order that the consumption and working of each engine may be independently checked, a separate gas-meter should be provided for each; it should be placed outside the engine-room in an atmosphere of normal temperature as an increase of temperature means an increase in the volume of gas for the same weight. A flexible gas-bag or bags should be provided between the meter and the engine, in order to reduce the effect of fluctuations of pressure in the mains. The ignition of the explosive mixture within the cylinder of a gas-engine without permitting escape of gas has

been a detail of some difficulty in the design of the engine. It is accomplished in various ways. In "flame-ignition" a portion of burning gas is carried through a small aperture in the slide when just closing. If the aperture becomes carbon coated, as often happens, missfires are occasioned. In "tube-ignition" a cast-iron tube is maintained at white heat by a Bunsen burner, and when the timing-valve opens, the charge, being partly compressed into an ignition chamber in communication with the tube, then ignites. "Electric ignition" is accomplished by causing an electric spark or shower of sparks to take place in the cylinder or in a chamber brought into communication therewith.

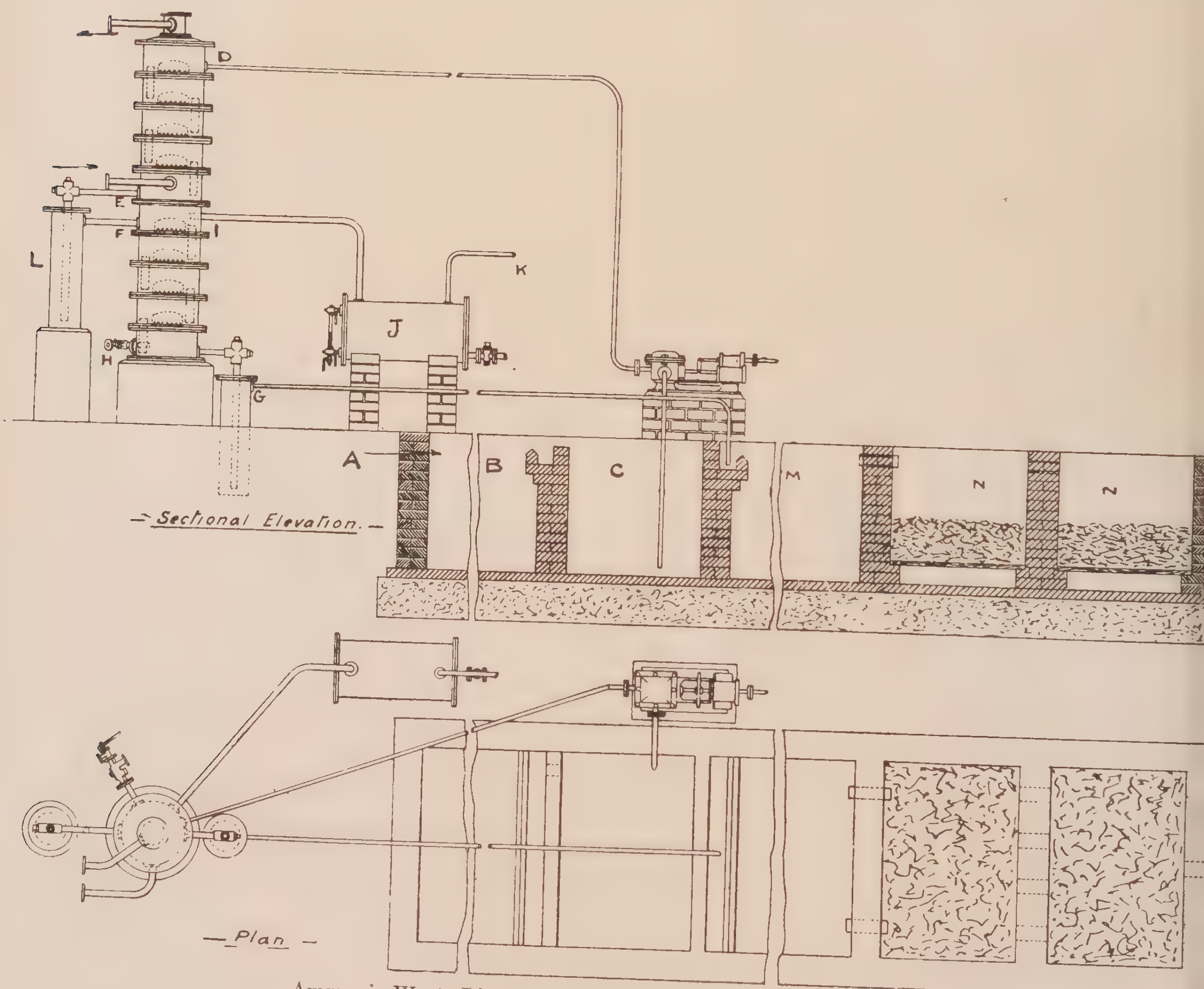
Gas Fuels.—The fuels most commonly used in gas engines are ordinary town coal gas, Dowson-Mond, or other cheap classes of power or generator gas. In the larger engines, notwithstanding the improvements made in economy of gas consumption, the price of ordinary town gas supply is usually too high to permit of its use to advantage except when working intermittently. In these circumstances, and where the ordinary gas is not available, a "gas-producer" plant may be installed to generate a non-illuminating gas costing (including all charges, depreciation, wages, &c.) from $2\frac{1}{4}d.$ to $4d.$ per 1,000 cu. ft., according to the size of the plant. These gases are poor in calorific value as compared with coal-gas, and proportionately greater volumes are required to evolve the same amount of heat. The calorific value of 1 cu. ft. of coal gas at atmospheric pressure and 32° F. is from 600 to 650 British thermal units, whilst that of a producer-gas varies from 145 to 165 thermal units per cubic foot. From 4 to 5 volumes of the producer-gas are therefore required to give out the same amount of heat as one volume of coal-gas, and the cost per 1,000 cu. ft. must be multiplied by this figure before comparison with coal-gas. Notwithstanding this, the producer-gas shows a large saving, which, with coal gas at 3*s.* per 1,000 cu. ft., may vary from 30 to 60 % according to the size of the plant.

The process of manufacture of Dowson gas, now so extensively used, consists in injecting a mixture of superheated steam and air through incandescent coke or anthracite and collecting the resulting gas. There is no external fire as with ordinary gas retorts, and the production is automatically regulated from the gas-holder without the employment of skilled labour to work the apparatus. Its heating value is equivalent to about 150 British thermal units per cubic foot, and the quantity of air required for its complete combustion is only from 1 to $1\frac{1}{2}$ volumes to 1 volume of the gas. The capacity of an engine cylinder is, therefore, suitable for either coal or Dowson gas, the gas and air valves being adjusted to admit more gas and less air. The products of combustion of Dowson gas must be expelled from the cylinder or their presence will cause the fresh charge to miss fire. This is done by what is called the "scavenger stroke" or its equivalent. The average fuel consumption for a gas-engine driven by Dowson gas varies from about 1 lb. per I.H.P. for the larger engines to $1\frac{1}{2}$ lb. per H.P. for the smaller sizes. In engines fed from the town gas supply the guaranteed consumption is now usually from 15 to 20 cu. ft. per I.H.P. per hour, according to the size of the engine and quality of the gas.

Testing Gas-Engines.—The testing of a gas-engine is, in many respects, very similar to a steam-engine, but there are important distinctions to be kept in view. Indicator diagrams cannot be entirely relied upon, though if carefully taken they are useful for practical purposes. The brake horse power of a gas-engine should always be taken as the measure of its duty in preference to the indicated. Very stiff springs must be used in the indicator (from $\frac{1}{120}$ to $\frac{1}{250}$) so that only the compression, explosion and expansion curves are clearly given by the diagram obtained. Besides the indicator diagrams taken during a trial, it will be necessary to note the brake readings of the spring balance and load on brake, the speed of the engine and number of explosions per minute, also the quantity of

gas used in cubic feet with its temperature and pressure, as well as the weight of the jacket-water and its inlet and outlet temperatures. The reading of the barometer and, if possible, the temperature of the exhaust are also noted. W. H. M.

Gas Water-Liquor Purification.—The impurities washed away during the process of purifying gas are principally ammonia, sulphuretted hydrogen, carbonic acid and cyanogen compounds. Phenols and cresols are also present in this ammoniacal liquid through cooling of the hot gas. The ammonia is valuable as a fertilizer. It is recovered by boiling this liquor (adding lime at an intermediate stage for the decomposition of combined ammonia) and usually absorbing the evolved gases in sulphuric acid. From 100 tons of coal there will be obtained one ton of sulphate of ammonia value about £12. The costs, consisting of acid, lime, coke, labour, bagging, and wear and tear, amount to £3 15*s.* 0*d.*, thus leaving a profit per 100 tons of coal (equal to 1,000,000 cubic feet of gas) of £8 5*s.* 0*d.* From one ton of sulphate of ammonia there is produced about 2,500 gallons of a waste liqour containing free lime,



Ammonia Waste Liquor Purification Plant (Radcliffe's Patents).

hyposulphite, sulphate, carbonate, cyanide and sulpho-cyanide of lime, and phenols and cresols. It is antiseptic, and has an oxygen absorption test of between 400 and 600. Its common destination is the sewers. Since the development of the bacterial processes for the purification of sewage many local authorities have been obliged to exercise their powers and prohibit its discharge, because with this material present, the difficulties and expense of the problem of sewage purification is vastly increased. On the other hand gas undertakings have to face a considerable loss of revenue. While most large gas undertakings work up their liquor as above described, smaller concerns sell their product as liquor to a chemical works. In the locality of these chemical works the problem is still further increased in difficulty. A process has been introduced by J. Radcliffe, of East Barnet, for the purification of this ammonia effluent, and is now working at a number of gasworks. With the ammonia gas produced by boiling as described also are evolved carbon dioxide and sulphuretted hydrogen, and upon absorption of the ammonia by acid these gases remain, and are employed for the purification of the waste liquor. The liquor enters the plant at *A*. The solids are removed in *B*, the clear liquor is pumped from *C* to *D* and passes to *E*. The waste gases from the liquor heater of the sulphate plant enter by *E* and leave at the top, passing to the condenser of the sulphate plant, the working of which is in no way interfered with. The lime is precipitated and phenoloids decomposed. About three volumes of air are mixed with the waste gases employed by means of the injector shown, a separate air pipe leading to the section above *E*. The liquor re-enters at *F* and passes to *G*. A large volume of air is injected at *H*, leaving at *I*, carrying away phenoloids and other liberated impurities. A condensate containing these accumulates at *J*, and thence is led to a fire *K*. Cyanogen compounds are more completely removed if necessary by replacing *L* with a tank for settling out carbonate of lime, and introducing a small amount of vitriol continously at *F*. The liquor passes to settling tank *M* and filter tanks *N*. The bacterial effect of the purified effluent was determined with sewage effluent, adding various amounts as below to sewage, incubating five hours at 32° C. (by O. Hehner). "Sewage without addition, bacteria per c.c., 2,419,000; sewage plus 4 % effluent bacteria per c.c., 2,337,000; sewage plus 6 % effluent bacteria per c.c., 2,475,000; sewage plus 8 % effluent bacteria per c.c., 3,211,000; sewage plus 12 % effluent bacteria per c.c., 3,846,000.

"Up to 12 % the liquid has not only not antiseptic action on bacteria but greatly stimulates their growth and development." These plants have been successfully working for years in works which have been compelled to cease working their ammonia recovery plant.

The cost for labour and material are nothing and the outlay small.

Gauging Streams, &c.—The simplest way of ascertaining the flow of a small stream is to catch the water in a vessel of known capacity and to make a careful note of the time taken to fill it. Several trials should be made in order to establish a mean. Such a

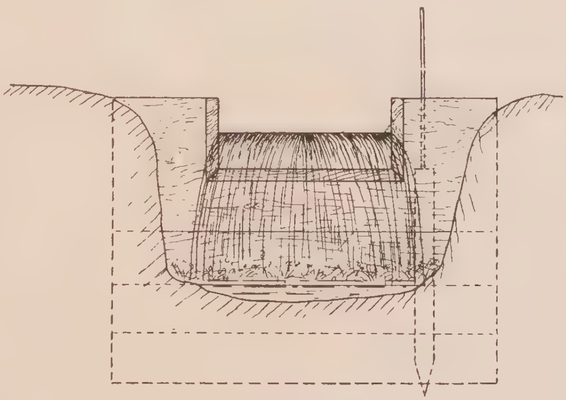


FIG. 1.

method is, necessarily, only applicable to very small supplies. For measuring larger volumes of water, gauging with a weir is the most reliable system. The weir is formed by damming the stream with a plank and allowing

the water to flow freely over a rectangular notch cut in the same (see Figs. 1 & 2). The width of the notch should not exceed two-thirds that of the stream and its depth must be sufficient to pass all the water that is to be measured. The edges of the notch should be bevelled, as shown, and any leakage at the sides or bottom of the plank prevented by the use of puddled clay. The depth of water flowing over the sill should not be more than a quarter of the total depth on the up-stream side, and the dam should be high enough to form a reservoir through which there is no perceptible current. The bottom of the notch must be set truly horizontal by means of a spirit level.

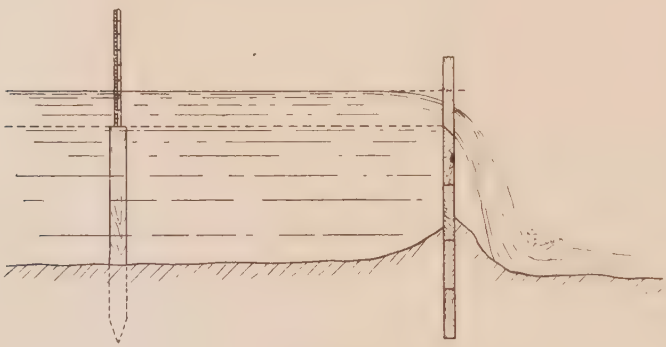


FIG. 2.

A gauging stake is then driven in until its top is exactly level with the sill of the notch; this stake should be placed in the still water well away from the depression that occurs in the vicinity of the overfall, so that the true depth of the flowing section may be measured. A thin rule should be used with its edge in the direction of the current. The quantity of water passing over the weir may be calculated with sufficient accuracy for all practical purposes by the following formula:—

$$Q = 4{\cdot}81\, L. \sqrt{h^3}$$

Q = Discharge over notch in cubic feet per minute.

L = Length of notch in feet.

h = Height of water above top of stake in inches.

A weir with a V-shaped notch is easier to construct, and, as the breadth of the overflow bears a constant proportion to the height, is preferable to a level notch when the volume of water is sufficiently small to permit its employment. The notch must be an exact right angle, with its (inverted) apex level with the top of the stake. The edges should be bevelled on the outfall side and the weir formed in the same manner as for the rectangular notch. The discharge may be calculated by the following formula:—

$$D = 1{\cdot}978\, h^2 \sqrt{h}.$$

D = Discharge in gallons per minute.

h = Height of water above top of stake in inches.

If the stream is too wide, or its banks are unsuited to the use of a weir, a fairly reliable estimate of the flow may be arrived at if the average cross-sectional area of the stream and the velocity of the water are known.

The velocity of the water may be ascertained by observing the mean time that a float (such as a bottle sunk to the cork) occupies in travelling between two points—say 100 feet apart. Several experiments should be made in the most uniform section of the stream that can be found, and the float should be cast into the water well above the starting point. Owing to the friction of the sides and bottom of the channel the velocity of the water will not be uniform; the actual quantity passed will be less than that indicated by the float, by an amount which depends upon the material of which the channel is composed and, to some extent, its shape. The formula may be stated thus:—

$$q = \frac{D\,B\,L}{T\,K}.$$

q = Flow in cubic feet per second.

D = Average depth of wetted channel in feet.

B = Average breadth of ditto.

L = Distance traversed by float in feet.

T = Average time, in seconds, taken by float from point to point.

K = Co-efficient = ·65 for rocky stream beds.
= ·70 for small earthen channels.
= ·80 for large ditto.
= ·85 for smooth conduits.

The results by this method are only approximate, and it should not be resorted to when others are admissible.

The mean velocity of a stream can be more reliably determined by taking observations at various points with a current meter. This usually consists of a small screw propeller driven by the water and combined with a revolution counter, the relation between the revolutions of the screw and the velocity of the current being established by drawing it through still water at various speeds.

When it exists, and permits a free discharge to the water, a sluice affords a very convenient method of obtaining the volume of a stream. The gate must be opened until it exactly passes all the water coming down the stream. The breadth and height of the opening and the depth from the surface of the water to the centre of the orifice must then be carefully measured. The discharge may be found thus :—

$$q = 8{\cdot}025\, A\, K. \sqrt{H}$$

q = Quantity of water in cubic feet per second.
A = Area of orifice in square feet.
K = Coefficient = ·62 for a sluice without side walls.
= ·96 for a sluice with walls in a line with the opening.
H = Head = surface of water to centre of orifice in feet.

For cylindrical extensions, of the same diameter as the orifice, but with a length ranging from twice to sixty times the diameter, K varies from ·82 to ·62. E. L. B.

Gel, a term introduced by Graham to denote the gelatinous result of the coagulation of Colloidal Matters (*q. v.*).

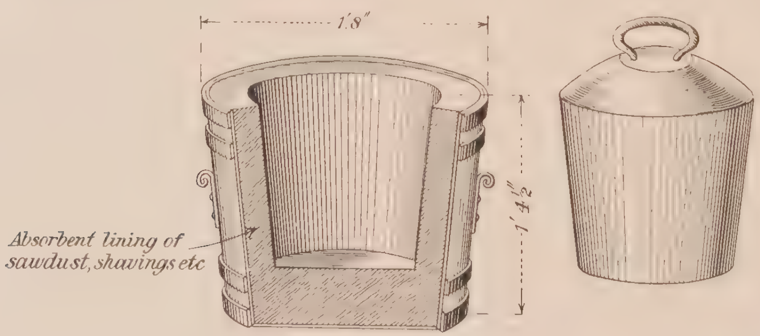
"Germs" of Disease.—Numerous diseases are now known to be due to the presence in the system of very minute forms of animal and vegetable life, popularly spoken of as "germs." Many of the specific infectious diseases, of which Professor Osler, in his "Principles and Practice of Medicine," enumerates twenty-five, are known to be due to bacteria, and it is probable that all of them are due to similar organisms. Proof is at present wanting in many cases, and in some it may ultimately be found that the "germ" is an animal rather than a vegetable parasite. Thus malarial fever was for long considered to be an infectious disease allied to typhoid fever, but recent researches have proved that the specific organism is a sporozoa, and that human beings are infected by the bite of certain mosquitoes, in the bodies of which the microscopic animal undergoes one stage of its singular development. Bacteria are parasitic fungi, and it is believed that some may be so small as to be beyond the limit of visibility under the highest possible magnifying power of the microscope. Even with the highest available power they appear like single cells, ranging in form from a sphere to a short cylindrical rod. According to their forms they are usually divided into three groups.

Cells, spherical or nearly so—Coccii cells, rod-shaped and straight or but slightly curved—Bacilli cells, elongated and twisted or forming spiral threads—Spirilla.

Erysipelas, pneumonia (certain forms of), gonorrhœa, Malta fever and cerebrospinal meningitis are the chief diseases known to be due to cocci, anthrax, plague, typhoid fever, dysentery (certain forms of), influenza, diphtheria, tetanus, tuberculosis, leprosy and glanders are due to bacilli, while the germ of cholera is a spirillum. Many of these bacteria can be made to vary enormously in virulency by different methods of cultivation, and when introduced into the system they may or may not cause disease. (*Vide* "Zymotic Diseases.") The mere presence of these germs is not sufficient to account for their effect, and

in the majority of cases there is no doubt that these effects are due to specific poisons, "toxins," which the germs produce during their growth. They may enter the system through abrasions of the skin or internal mucous membrane, through the lung tissue, or through the alimentary canal. They may multiply upon the surface of the tonsils and by their growth destroy the tissue beneath and so gain access to the system. The effects produced vary considerably, as will at once be realised by comparing the history of a person suffering, for example, from typhoid fever due to the typhoid bacillus with that of one suffering from phthisis due to the bacillus of tuberculosis. Many of these germs are capable of being grown outside the human body on suitable media. Most of them are easily destroyed by a temperature of 80° C., but a few, such as the bacillus of tetanus and of anthrax, will withstand a temperature of 100° C. for a short time. These latter are spore-bearing bacilli. The majority are non-spore bearing and multiply by simple fission. Those producing spores only do so under certain circumstances, and these spores are much more resistant than the bacilli, and may survive under conditions which rapidly prove fatal to the bacilli themselves. (*See* "Zymotic Diseases" and "Bacteria.") J. C. T.

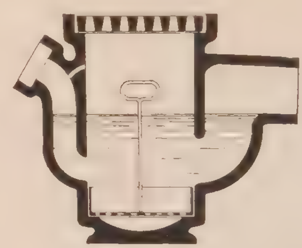
Goux Tub System.—This is one of the conservancy methods of dealing with the



Goux.

collection of human excreta, and has been in use at Halifax for many years. The principle involves the lining of the tub or pail with some absorbent material with the object of securing dryness, retarding decomposition, and preventing nuisance. The size and class of pail is shown in the accompanying figure, and, by the employment of the mould, also illustrated, absorbent materials such as sawdust, shavings, shoddy, stable litter, leaves, or other like substances, are compressed into the form of a lining some 6 in. in thickness, into which the excreta is received. When the pails are received for collection the upper portion of the lining is broken up and scattered over the contents with the object of rendering the same as free from odour as possible.

Grease Traps.—Surface traps or gullies designed to prevent also the passage of grease

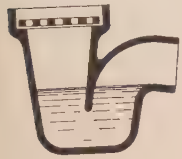


Grease Trap.

from scullery sinks into drains. These traps are usually provided with a dipped inlet and outlet and offer a large water area for the cooling of the grease. Frequently they are supplied with a bucket or tray which when lifted out of the trap removes the solidified grease from it. Grease traps are liable to give rise to nuisance and are best avoided if possible.

Gullies, or Surface Traps.—These are traps placed on the inlet end of drains provided for the reception of rain and waste water. Their use is to prevent the issue of drain air at those points. The sanitary forms

of these traps are of siphon shape, and that illustrated is typical of them all. They vary mostly as regards the form of inlet, and are available with or without branches for the reception of waste pipes, &c. Some are provided with flushing rims, that being a convenient method of connecting a flushing tank to drains. In selecting gullies, preference should be given to those which provide a sufficient seal with a minimum quantity of water, and which have a good base, as the latter will greatly facilitate proper fixing. Rain-water and waste-water pipes may be arranged to discharge into the gullies either above or under the gratings of the traps, but should in all cases do so above the water level.



Gully.

Head (pressure, loss of).—Water, or other liquids, when flowing through pipes encounter a resistance due to friction and, to a slight extent, the viscosity of their particles.

The pressure required to overcome this resistance and to propel the liquid through the pipe, is conveniently expressed in the terms of the head or height of the liquid that would correspond with that pressure.

The friction of water in pipes increases nearly as the square of its velocity and directly as the length of the pipe; but it is inversely proportional to the hydraulic mean radius of the same (*i.e.*, the cross-sectional area divided by the circumference).

Any alteration in the direction of the flow by bends or, more particularly elbows, increases friction, and the latter should always be avoided if possible. Sudden contractions or enlargements are also undesirable, in that they create eddies. The condition of the interior surface of the pipe is likewise an important factor, the friction in encrusted pipes being about twice that in perfectly clean, smooth pipes, added to which there is a further loss by reduction of area. The loss of head in clean cast-iron coated pipes may be found as follows:

$$H = \frac{V^2 L}{K^2 \times \cdot 25D}.$$

H = Head in feet.

V = Velocity of water in feet per second.

D = Diameter of pipe in feet.

L = Length of pipe in feet.

K = A co-efficient depending upon the size of the pipe, which varies as follows:—

Diam. of pipe in feet ..	·25	·5	·75	1·0	1·25	1·5	1·75	2·0
Value of K ..	70	86	97	106	113	118	121	123
Diam. of pipe in feet ..	2·5	3·0	3·5	4·0				
Value of K ..	127	131	135	138				

Similarly V will be equal to $K\sqrt{\frac{D}{4} \times \frac{H}{L}}$.

The discharge in cubic feet per second will obviously be equal to the sectional area of the pipe in feet multiplied by V. (*See* "FLOW OF WATER IN PIPES" and "HYDRAULIC MEMORANDA.") E. L. B.

Heat, Utilisation of.—(*See* "DESTRUCTORS.")

Heating. — **Open Fires — Hot Water and Steam Heating — Hot Water Low-Pressure Systems—Two-pipe Method—One-pipe System — Hot-water Boilers — Selection of Boilers — Radiating Surfaces for Ordinary and Horticultural Buildings—High Pressure or Perkins System — Heating Water by Steam — Steam Heating — Low Pressure — Vacuum Systems — Ventilation and Heating—Air Warming-stoves.**— Ideally the warming of rooms and buildings is to raise and maintain the air and surfaces at an even and agreeable temperature throughout, with a minimum of fuel and attention, and without adding impurities to the air, creating draughts, or unduly robbing the air of its invigorating properties and humidity.

OPEN FIRES possess a cheerful appearance. Bodily warmth may be quickly absorbed, ventilation is assisted, and the fire is available for domestic purposes. On the other hand, there is considerable disproportion of heat emitted to fuel consumed; much dirt and

labour is involved, and the room, especially if large, is not equably warmed. Although open fires provide perhaps the most healthy means of warming rooms, their use in towns adds seriously to the pollution of the atmosphere.

Hot Water and Steam Heating.—A more equable temperature may be maintained with a considerable saving of fuel by warming the house or building with hot water or steam.

Hot-Water Low-pressure Systems.—In low-pressure systems an open pipe is carried above the supply cistern, the pressure being thereby limited to the head of water. A boiler is placed below the rooms to be warmed, and one or more pipes—flow and return pipes —carried along or returned in the direction in which heat is to be emitted. "Flow" pipes leave the top of boiler and ascend, permitting convection currents to rise therein, whilst "return" pipes descend, the water therein returning by gravitation to the boiler, entering it near the bottom to ensure circulation throughout. The system should, as far as possible, be arranged to obtain the maximum vertical, as opposed to horizontal piping, the

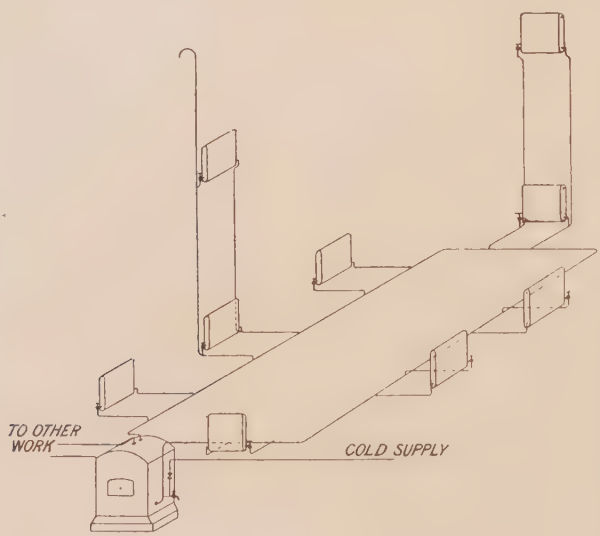


Fig.1.—One-pipe Steam System.

size of mains and branches proportioned to the radiating surface required, and a boiler of ample proportions provided. Low-pressure hot-water heating may be sub-divided as follows:—

Two-Pipe Method.—Flow and return pipes are carried along side by side, the branches to

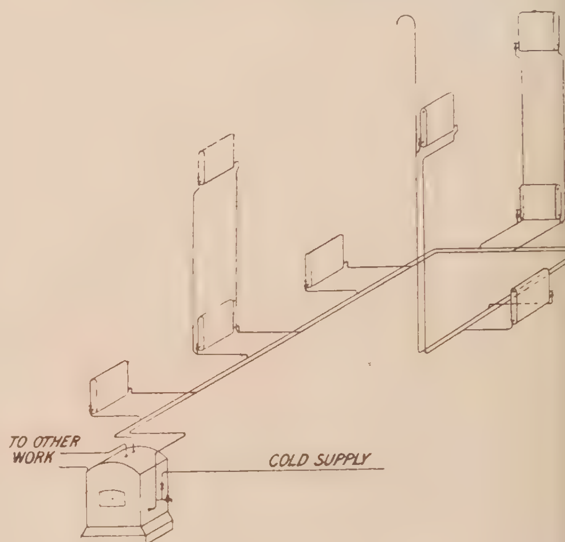


Fig. 2.—Two-pipe Hot-water System.

the different floors and radiators being taken off the flow and return pipes. Objections to this method are, (a) two pipes must be run to every part of the premises to be heated; (b) radiators being connected to both flow and return, short circuiting may result.

One-Pipe System.—This system has for its principle the running of one or more large circuit mains. Each main leaves the top of the boiler and rises as vertically as possible to its highest point, returning to the boiler by way of the radiators. Branches and flow and return connections are taken from the return main—in some cases a few may be taken from the flow—the same as if directly off the boiler; flow connections from top of main and return connections from side of main furthest from boiler. As single mains are used they require to be larger than with the two-pipe system; the volume of water to be carried is, however, practically the same. Advantages of the "one-pipe system" are, short-circuiting is impossible, and generally the constructional cost is lower.

A modification of the "one-pipe system," known as the "overhead or drop system," is largely adopted in buildings possessing similarly planned floors. The main pipe is carried direct to the top floor or attic above, distributing branches being here taken off and "dropped" to return to the boiler. Radiators are connected to the "drop" pipes, the feed at the top and return at bottom. No air cocks are required, but an expansion cistern or tank through which the whole system is vented is required above the highest part of main. With this system a more rapid circulation is obtained, and smaller pipes may be used.

Hot-water Boilers.—The success of any hot-water apparatus is dependent upon the boiler. The amount of radiating surface, including mains and branches, should be ascertained, and a boiler of ample proportions provided. Uniform rating of boilers is much needed. A common basis is to allow 1 sq. ft. of boiler surface to 35 ft. of 4-in. pipe. This ratio is reduced to 1 ft. to 25 ft. by at least one maker. Regard should, however, be had to the fact that the efficiency of boiler surface varies with its position relative to the fire. A better method is to list the boiler capacity in B.T.U. per hour. This should be based on an apparatus working under normal conditions. The practical test in all cases is the fuel consumption and heat transmission when banked to last a specified time. As the boiler-capacity should always be at least equal to the radiator emission required to properly warm the various rooms, &c., the capacity may be calculated by multiplying the heat emission per square foot of radiating surface by the total area of radiators, mains and branches. The heat emission in B.T.U. of hot-water radiators and pipes varies from about 200 to 150 per hour with the temperature of the air about them at 60° F. A reliable estimate of boiler power required may be obtained by multiplying the total area of radiators, uncovered mains and branches by 180, the result giving the required capacity in B.T.U. per hour.

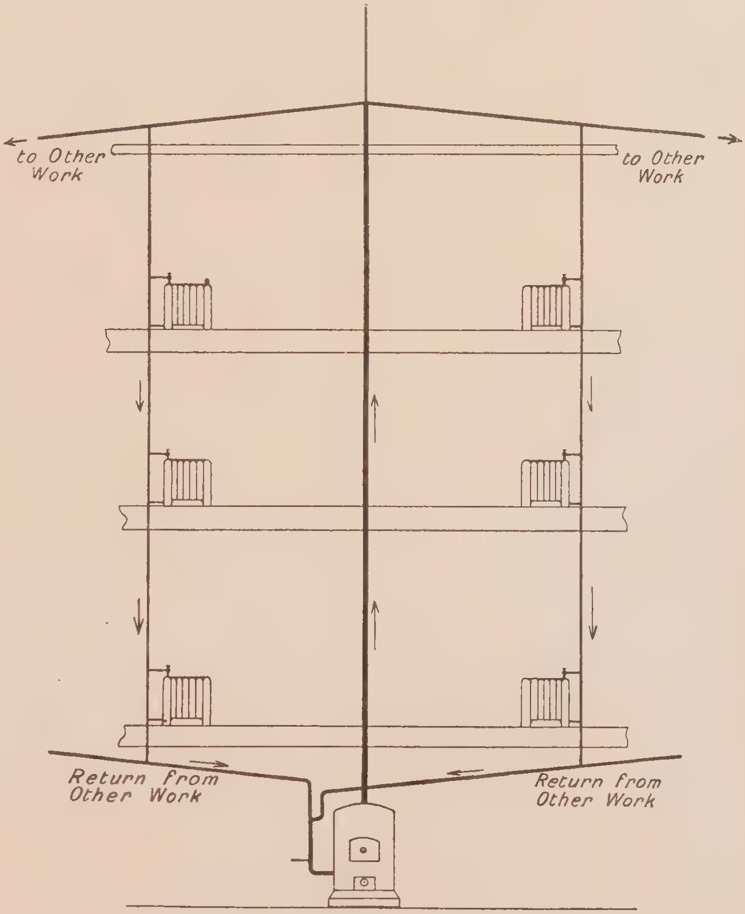


Fig. 3.—Hot Water Overhead or Drop System.

Selection of Boilers.—Brick-set boilers are now giving way to "independent" types. These are compact, occupy less space, and are more easily examined and repaired. Cast-iron sectional boilers are largely used. They

possess many advantages, and, with proper care, should last longer than wrought-iron, but are somewhat more complicated, and the thickness of the castings are not always uniform throughout. In a well-designed type of this class a large heating surface is exposed to the fire and hot gases. The grate area is well-proportioned, and the front well fitted for draught regulation. These boilers are fairly economical in fuel.

Radiating Surface Required.—This may be estimated by either of the following methods: (1) By calculating the heat in B.T.U. required to raise the temperature of air contained in and passing through the apartment, *plus* the heat lost through the several materials, walls, windows, &c., enclosing the room (in most cases exposed surfaces only need be considered), and dividing the sum of the whole by the B.T.U. emitted per square foot of radiating surface, which for radiators and low pressure hot water, to maintain a temperature of 60° F., may be taken as 160°. Owing to leakage of air through ill-fitting doors, windows, &c., two to three air changes per hour should be allowed. The following table gives the coefficient in B.T.U. to raise the temperature of air, also the heat transmission through walls, &c. The calculation is in B.T.U. per hour for 1° difference in temperature of air, and also on the two sides of the walls, &c.

Heat Losses.

		Coefficient.
Air	1 cu. ft.	·019 B.T.U.
4½ in. Brick wall	1 sq. ft.	·5 ,,
9 ,, ,,	,,	·35 ,,
14 ,, ,,	,,	·27 ,,
18 ,, ,,	,,	·23 ,,
Single windows	,,	1·03 ,,
Double ,,	,,	·48 ,,
Single skylights	,,	1·11 ,,
Double ,,	,,	·5 ,,
Corrugated iron roofs	,,	2·17 ,,
Ceilings close to roof	,,	·32 ,,
,, with good air space	,,	·13 ,,
Floors (12 in. concrete and wood)	,,	·17 ,,
,, (wood on joists)	,,	·52 ,,
Doors 1½ in. thick	,,	·45 ,,

To ascertain the loss in B.T.U. per hour from any room or building, multiply the air coefficient in table by the cubic capacity and the air changes, and by the difference between the required internal and the external temperature. To this must be added the sum of the products of the different surfaces multiplied by their respective coefficients and by the difference between the external and internal temperature. Dividing the total by 160 gives square feet of radiating surface required to maintain a temperature of 60° inside when 30° outside. Or (2), a simplified formula may, in ordinary cases, be used. The formula by W. Jones, based on a lifelong experience, is easy of application:—

For Ordinary Buildings (not horticultural).—To obtain 60° inside when 30° outside, and water 170°

$$S = \frac{G}{6} + \frac{W}{12} + \frac{C}{120 \text{ to } 160^*}.$$

S = Ft. super radiation required for the stated temperature.
G = Ft. super glass.
W = Ft. super exposed wall.
C = Cubic capacity.

* 120	for rooms	under 5,000	cu. ft. capacity.
140	,,	5,000 to 25,000	,, ..
150	,,	25,000 to 100,000	,, ..
160	,,	over 100,000	,, ..

The above rule assumes the loss through doors, walls, and windows to be from two to three changes of air per hour. If more air changes are required, add cubic capacity ÷ 300 for each additional change.

For Horticultural Buildings.—The following rule by W. Jones gives the feet sup. radiating surface required for the same temperatures as in last:—

$$S = \frac{G}{6} + \frac{W}{12} + \frac{C}{150}.$$

A table of coefficients for use with other temperatures is given in "Heating by Hot Water," by W. Jones. No rule or combination of rules will be applicable to every case; *e.g.* an increased amount of radiating surface will be required in the case of rooms or buildings exposed to severe weather.

High Pressure or Perkins System.—This system has been in use upwards of 60 years; its use, however, is not nearly so extensive as the low pressure system. It consists of a series of very strong wrought-iron tubes—similar to hydraulic tubes—usually of $\frac{7}{8}$ in. bore, screwed together with right and left hand threads. One of the ends of the tube to be drawn together is tapered, inside and out, to a conical edge, the other end being trued to a flat face. Powerful tongs are required to draw the tubes together, the actual joint being made by forcing the coned edge into the flat face of the opposite pipe. The boiler is coiled of the same description and size of tube, the number of coils being proportioned to the quantity of radiating surface. At the highest point of the apparatus is fixed an air vessel or expansion pipe, the capacity of which must be carefully proportioned to the quantity of water contained in the apparatus. Water is pumped into the apparatus from a point near the boiler until it reaches an overflow placed at the bottom of the expansion pipe. The overflow is then plugged, the apparatus being hermetically sealed. It is afterwards tested to a pressure up to 3,000 lbs. per sq. in. Owing to the apparatus being sealed, the water may attain a temperature of 300° to 600°, being, of course, accompanied by high pressure; and the expanded water compresses the air in the expansion pipe. Considerable experience and special appliances are required to properly erect this system; but although the apparatus may appear to be highly dangerous, it is not so in fact, as any defect manifests itself at the boiler and puts the fire out. Advantages claimed for this system are: The temperature of the water is quickly raised. It may be used to assist ventilation (in this case it should be filled with anti-freezing liquid). The pipes are smaller and neater in appearance. The system is suitable for large buildings that are well ventilated. The disadvantages are: Repairs necessitate the calling in of a specialist, preferably the erecting firm. The high temperature of the pipes often produces unpleasant smells, due to the burning of organic matters present in the air. Pipes must be kept well away from woodwork. The system is specially suitable for high temperatures such as are required for laundry purposes, &c.

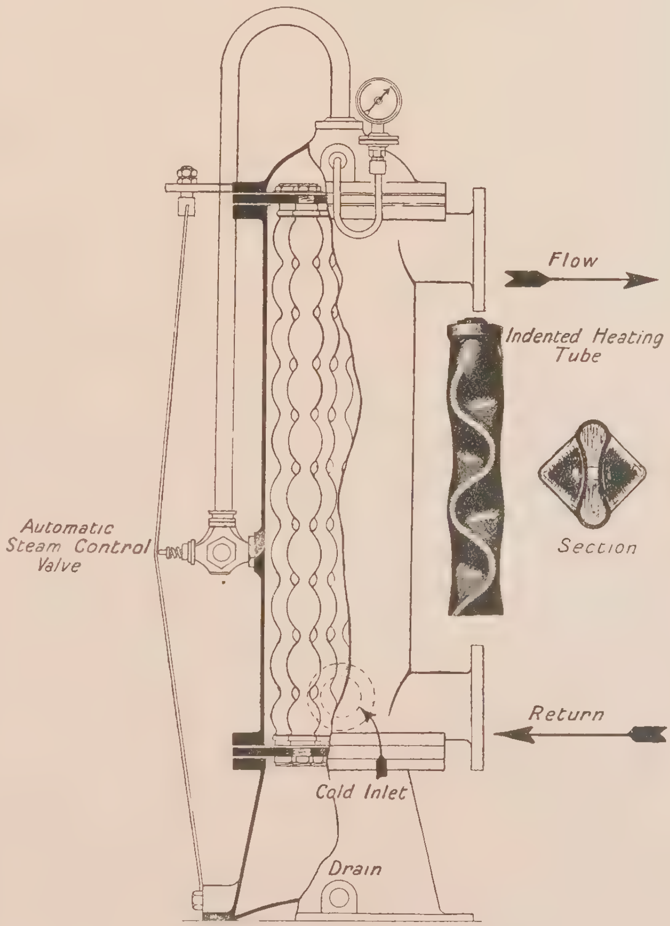


Fig. 4.—Vertical Steam Calorifier with Indented Tube.

Heating Water by Steam.—Where a steam supply is available the building may be

warmed by water heated by contact with steam-heated surfaces, or by allowing steam to pass direct into the water. Warming by steam-heated surfaces is accomplished by steam-heaters, or "calorifiers," generally cylindrical in form, which takes the place of the hot water boiler, connections being similarly made thereto. Inside the calorifier there is usually a coil or series of tubes through which the steam passes, warming the water in contact with the outside of the tubes. The condensed steam is or should be ultimately returned to the boiler.

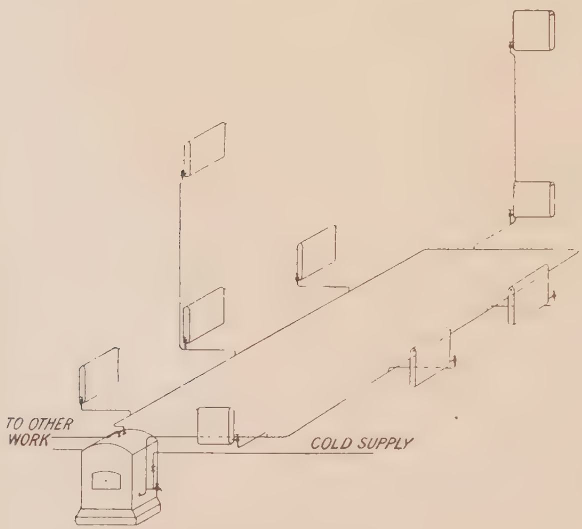


Fig. 5.—One-Pipe Steam Gravity System.

The power of steam-heaters or calorifiers varies with the temperature of steam and with the form of tube and general construction; 1 ft. super of steam-heated tube is usually much more effective than an equal amount of hot water boiler surface. Heating by the injection of steam is accomplished by means of an "injector;" the issuing steam warms the water and impels the same along its course. There is an amount of water added to the apparatus equal to the steam condensed, which must be allowed to overflow, and then returned to the boiler-house for use in the boiler. These systems are very suitable for large institutions with a central heating plant or boiler-house.

Steam Heating.—Steam is extensively used for warming public buildings, schools, factories, &c., and is undoubtedly superior to hot water for warming in conjunction with ventilation, as, for example, in the plenum systems. It may be economically employed where steam is generated for other purposes, exhaust steam being frequently and advantageously utilised.

Where a steam supply is not available and the building is of limited dimensions, as for residential purposes, hot water possesses many advantages and will doubtless continue in favour in this country. Generally speaking, a steam system requires a skilled attendant—a matter of importance in small buildings where the caretaker is expected to attend to the apparatus. Moreover, repairs are, if anything, more costly, and the temperature of the steam (unless under vacuum systems) is not easy of manipulation. For large buildings, however, steam possesses many advantages. Steam in condensing gives up its latent heat—approximately 966 B.T.U. per pound, which quantity of heat is dissipated by the pipes of radiators before the steam is entirely condensed. The latent heat is for practical purposes the same for all pressures, and no useful purpose is served by working at high pressure; in fact, the reverse is the case, owing to the higher temperature of the pipes, &c., burning up organic matter in the air, causing unpleasant smells, and also robbing the air of humidity. In a properly erected steam-heating system, the steam should be carried to the radiators with a minimum of condensation and be there dissipated. The water of condensation should be properly drained without interfering with the flow of steam, and be directly or ultimately returned to the boiler. Adequate provision should be made for the escape or removal of air from the apparatus. The system should be free from noise, and the steam generated and maintained with a minimum of fuel and attention.

Low-pressure—One-Pipe Gravity System.—

One or more large circuit mains are used, the highest point being practically directly over the boiler; from here the main descends until it returns to the boiler, entering below the water-line. Single connections are taken off the main to supply radiators. As the water returns to the boiler by gravitation, little attention is required, especially when a good form of automatic damper is fitted, to control the temperature of steam by draught regulation. A little water is periodically added to the boiler to replace any slight escape of steam. This is the cheapest system to erect, and when properly executed is entirely satisfactory.

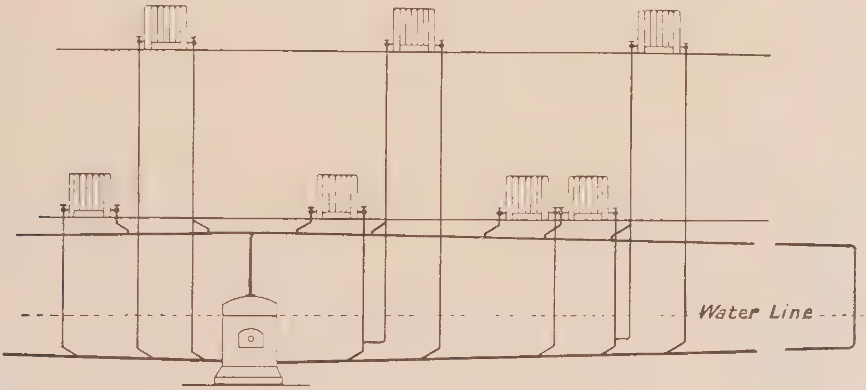


Fig. 6.—Two-Pipe System, Low Pressure Steam.

Low-pressure—Two-Pipe System with Wet Return.—The highest point is practically directly over the boiler; from here it gradually falls until the last radiator is passed, when the main at once drops below the water-line of boiler, returning to the boiler at that level. Two connections are required to radiators, the inlet from steam main, the outlet through which condensed water flows being taken direct to the return pipe, the end being submerged. Care should be taken that connections between two or more returns are made below the water-line of boiler. This system is more costly to install, but is held by many to be more silent than the "one-pipe."

Open-Pipe System.—This system is largely used in France, but is not common in this country. It has for its principle of operation the admission of only the maximum amount of steam that the radiator will condense when the controlling valve is full open. As the supply of steam is reduced, so will a proportionate amount of radiator surface be in use. A boiler is placed in a cellar or pit, a tank being placed about two metres above the ordinary water-line of boiler. Two pipes connect the tank to the boiler, one being taken from the bottom of tank and connected to bottom of boiler to ensure a return of condensed water; the other pipe—the "safety pipe"—connects the tank to the boiler at a point situated a few inches below the normal water-line. This pipe projects into the tank to allow sufficient capacity beneath its end for water to return to the boiler. An open pipe is taken from the top of the tank and carried beneath the fire bars. The main steam pipe leaves the top of the boiler whence it gradually descends as in previous systems; the end, however, terminates in a siphon, the height of which should provide a water column equal to the maximum boiler pressure. The end of the siphon is carried along, gradually falling until it enters the safety tank above the level of water therein. Return pipes from radiators are connected to the return pipe from the siphon and the ends of radiators are open to the atmosphere, the water of condensation being returned to the boiler *viâ* the safety tank. Advantages of this system are: (*a*), that small pipes may be used to supply

radiators; (*b*), the supply of steam, and consequently the temperature of the apartment, may be regulated; (*c*), its free discharge of air; (*d*), its noiselessness and low steam pressure. The use of an automatic damper regulator is indispensable.

Vacuum Systems.—Vacuum systems may be used with live or exhaust steam. These systems have for their principle the removal of air from the apparatus, and the creation of a partial vacuum which permits the steam to more freely enter and flow to all parts of the valve, which automatically opens when the apparatus is cold, but closes when in contact with steam, thus preventing the passing of steam to the condensed water pipes and mains.

Fig. 8 shows a small installation having only one radiator (2) and one coil (3), which may be termed the essential components of a vacuum system of any size. This small apparatus is supposed to be supplied either by live steam from the boiler on the right, or by exhaust steam from the engine on the left, since either or both together can be used in a

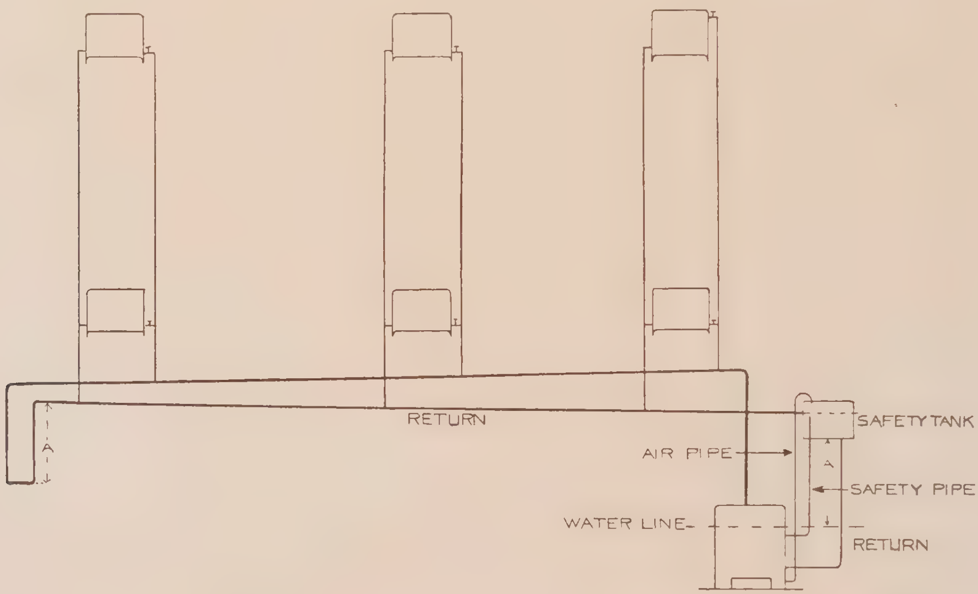


Fig. 7.—Open-Pipe System, Low Pressure Steam.

system. The whole of the latent heat of the steam is given off in the radiator, and the steam temperature may be regulated. One of the most popular systems is that patented by Warren Webster & Co., of America, the licensees in this country being the Atmospheric Steam Heating Co., Ltd. A brief description is as follows:—A pressure-reducing valve is fitted to reduce the pressure of steam entering the system to about ¼ lb. per square inch. A vacuum pump is fitted to the end of the condensation main to extract both the air and the water of condensation. On the outlet of radiators is fitted a thermostatic vacuum system. The live steam would first pass through a reducing valve (6) and a main valve (10), and the exhaust steam through a grease separator (7) and main valve (9), before reaching the rising pipe supplying the radiation. On each unit of radiation there would be an automatic valve (5) on the outlet, and a hand control valve (4) on the inlet, as well as a similar automatic valve (8) to drain the main and riser, and so keep the apparatus clear of water. From the automatic valves (5 and 8), small pipes would be taken into the main return or condense main, at the end of which is placed the vacuum pump (1). In

the working of such an apparatus the vacuum pump would be first started, and would exhaust the air from all mains, radiators, &c., through the automatic valves, so that when steam was admitted a partial vacuum (average not more than 10 in.) would everywhere prevail, and the only work required of the steam would be that of imparting its heat to the heating surfaces by condensation. Under these circumstances it is clear that a very quick circulation of the steam to the furthest limits of the apparatus is attained. The function of the automatic valves is important; they prevent "short circuiting" of the steam into the vacuum maintained return main, which itself would tend to destroy the vacuum, and so secure that no steam shall be wasted. Where exhaust steam is available for use, a back pressure valve (11) on the exhaust pipe is required to seal the apparatus. This is generally adjusted to open at ¼ lb. pressure. Gauges (12) are set up to indicate the pressures in the steam and return mains respectively. Among the advantages of a vacuum system may be mentioned: perfect circulation, absence of noise, controllability of temperature, economy in working and maintenance. The system has recently been installed in many important public buildings, and will undoubtedly be extensively used in the future. In fact, it may be said that vacuum systems and rapid circulation hot water (low pressure), are now generally favoured by heating engineers.

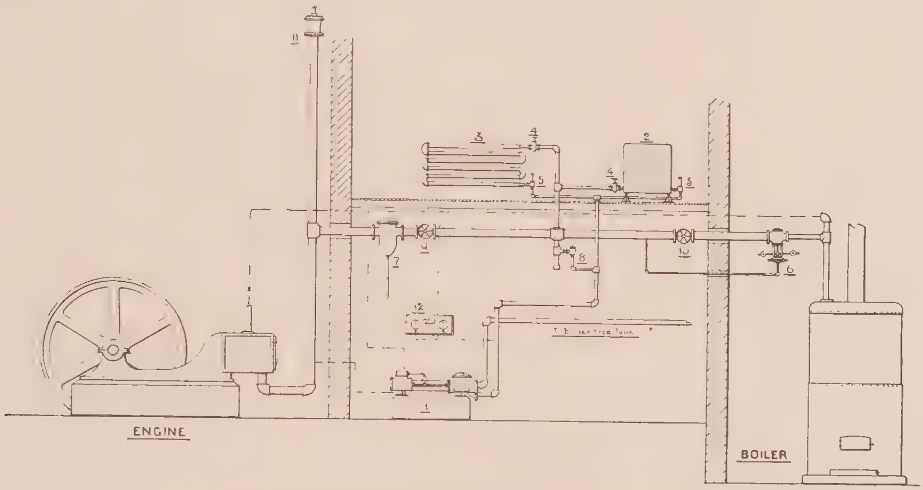


FIG. 8.—Vacuum System.

VENTILATION AND HEATING.—The heating and ventilation of rooms or buildings should always be considered in combination. Where a room is warmed by hot water or steam, ventilation may be obtained or supplemented by the use of ventilating radiators, the air passing through a grating in the wall behind the radiator, being warmed by contact therewith. Another method, but which is open to objection on the score of cleanliness, is the placing of a heating battery under the floor, encased in sheet iron; air passes through a grating, and is warmed by the heating battery, thence passing into the room. In plenum systems it is usual to warm the air at a point near the fan, the air being either forced or drawn through the battery of heating pipes. A much larger quantity of heating surface is required with systems designed to aid or be used in connection with ventilation. (*See* "VENTILATION.")

WARMING BY HOT AIR FURNACES OR CALORIFIERS.—The hot air furnace generally takes the form of a cast-iron stove, with its back corrugated or arranged with a number of fins or gills. The stove is placed below the

rooms and generally set in brickwork. The air to be warmed is conveyed in pipes to the furnace and heated by passing over the corrugated surface or gills, being afterwards conveyed to the different rooms by means of pipes or ducts. As this system brings in warm air, it is necessary to provide a sufficiency of suitable outlets. The system is difficult to install in existing buildings owing to the size of ducts compared with hot-water or steam pipes, necessitating much cutting away. The advantages claimed for the system are: (*a*) low cost of construction; (*b*) as fresh warm air is introduced, ventilation is necessary, and (*c*) the floor space of the room is not interfered with. On the other hand, the fuel consumption is excessive, and the temperature of the furnace frequently burns and dries the air. The stove is apt to be burnt through and permit sulphur fumes and probably overheated air or gases to enter the ducts and set fire to the building. It cannot be easily installed in existing buildings. In every case air should be drawn from an

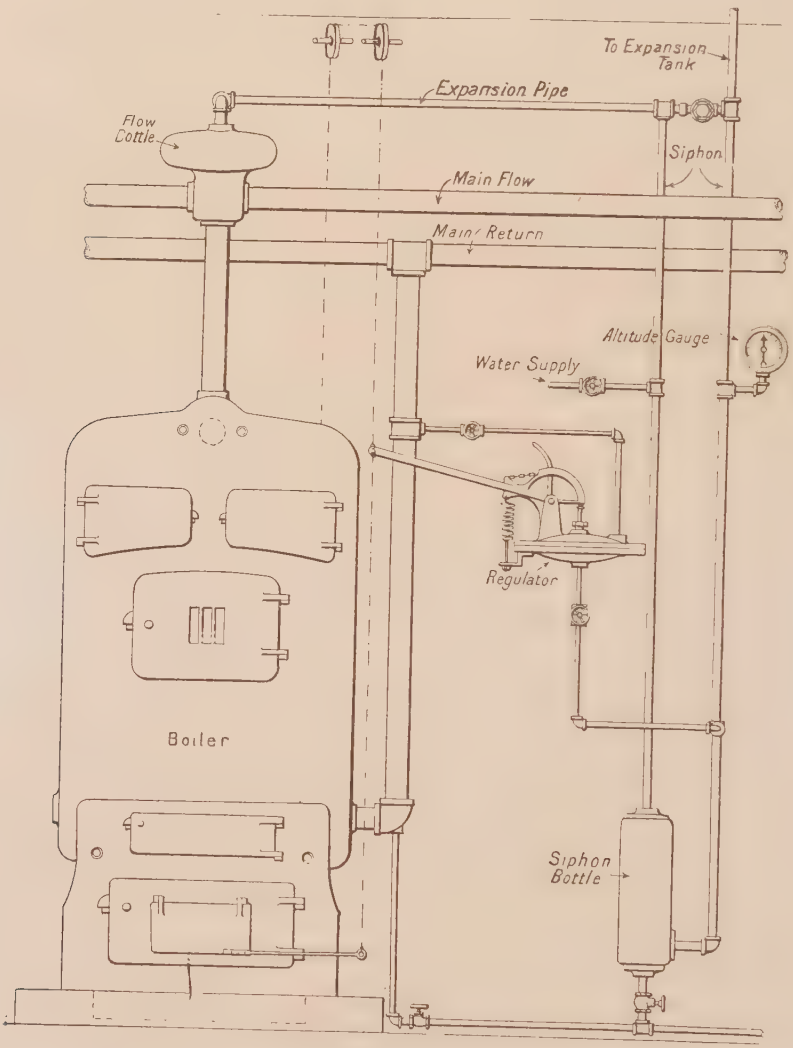


FIG. 9.—"Beck" Rapid Circulation Hot Water Apparatus.

unpolluted source, the heating chamber and ducts should be occasionally cleansed, and the air humidified when possible, and adequate exhaust ventilation provided.

Air Warming Stoves.—These stoves are very suitable for many buildings, and are extensively used for hospitals. A good description of such a stove is that manufactured by Messrs. Shorland. The "Galton" air warming stove is also well known. In all such heating appliances the air is drawn from outside and warmed by contact with the exterior of the stove, afterwards passing into the room—the cheerful appearance of the fire not being interfered with.

The "Beck" Rapid Circulation Hot Water Apparatus.—This simple but ingenious apparatus (Fig. 9) is primarily based on the recognised fact that ebullition, or the production of steam bubbles in an ascending flow pipe may have the effect of causing a considerable acceleration of the circulation, provided that suitable means are employed to regulate the ebullition, which unchecked causes shocks and noise. From an ordinary hot water boiler an ascending main flow-pipe is taken up into a pocket or bottle, from the lower part of which the circuit pipes are taken, while from the upper part a pipe is led first down through a deep siphon and then directly up to the expansion tank. In operation the steam bubbles, being lighter than the water, reach the upper part of the pocket, where they accumulate in quantity sufficient to cause a displacement of the water in the siphon towards the expansion tank. This displacement is taken advantage of to actuate a diaphragm or other form of regulator, which, through a suitable arrangement of pulleys and chain, acts upon the ashpit and smoke-pipe dampers—checking the fire and stopping the production of further steam bubbles. As soon as the temperature by this means has diminished, the steam condenses, causing a reverse displacement, which, through the regulator, acts on the fire to render it again more active. The effect of the arrangement described is to prevent the steam bubbles passing into the heating circuits at all, while taking advantage of their presence to cause a considerable acceleration of the water in the circuit pipes, and the practical result on the hot water apparatus is a very considerable reduction of the sizes of all the circuit pipes, and of all the radiation. —(*See also* "Hot-Water Supply".) W. F.

Hermetically Sealed.—A vessel, tube, or other enclosure is said to be "hermetically sealed" when it is closed completely against the passage of air, gas, or other fluid by fusing the extremity or opening of such vessel. The term is sometimes less correctly applied to any air-tight closure, and is also commonly used in connection with sanitary fittings, traps, pipe-joints, &c., which are proof against the passage of sewer gases.

"Hermite Process" of Sewage Purification. This system was installed for the purpose of disinfecting the sewage in a main line of intercepting sewers in Ipswich by Messrs. Patterson & Cooper, Engineers, Westminster. A deodorising and antiseptic fluid was produced by electricity from sea water, or from a solution of magnesium and sodium chlorides. This fluid was put into the drains or applied to the flushing of w.c.'s, much in the same way as in "Conder's process" (*see* "Conder's Sulphate of Iron Process"). In Ipswich the antiseptic fluid was admitted at the head of the main sewer, and the organic constituents in the sewage were oxidised thereby; but the process was discontinued about the year 1905.

Horse-Power.—The indicated horse-power of an engine is readily calculated from the indicator diagram (*see* "Indicator"), and for this purpose the mean effective pressure per square inch within the cylinder must be found. This is done in practice by dividing the diagram into ten parts by equidistant vertical lines, then scaling off the pressures from the diagram at the middle of each division within the enclosed curve, and finding

the average by dividing the aggregate of the pressures so scaled by ten. Having found the mean pressure acting on the piston throughout its stroke, the following rule may then be applied to find the horse-power, viz.: Multiply the area of the piston in square inches by the mean pressure per square inch, and by the piston speed in feet per minute; then divide the product by 33,000 ft. lbs. per minute (the equivalent of one horse-power per minute), and the quotient is the required indicated horse-power. This rule is usually put in the form of a formula, thus:—

$$\text{Indicated horse-power} = \frac{PLAN}{33{,}000}, \text{ in which}$$

P = the mean pressure on the piston in lbs. per square inch.
L = length of stroke in feet.
A = the area of the piston in square inches.
N = the number of strokes per minute.

The "brake," "actual," or "effective" horse-power of an engine is the measured horse-power given off from the crank-shaft of the engine; or, may be described as the net effective horse-power available for external work, and as shown by the friction brake. It is the "indicated horse-power" as given by the above scale, less the power required to drive the engine itself, which latter may vary from 10 to 25 per cent. according to the type and size of the engine. The "mechanical efficiency" of an engine is the ratio of the brake to the indicated horse-power,—thus mechanical efficiency:—

$$= \frac{\text{Brake horse-power}}{\text{Indicated horse-power}}.$$

The term "nominal" horse-power, though gradually becoming obsolete, is still used in England to express certain proportions of cylinder, but has no generally recognised value as a standard of measurement. The use of the term is now largely discarded owing to its having gradually receded so far below the actual horse-power, but it is found convenient for rating purposes to have a rule for estimating the power of an engine from its general dimensions. The nominal horse-power may be taken at about one-sixth the indicated horse-power.

Hot Water Supply.—**General Systems—Tank—Cylinder—Combined Systems—Boilers and Incrustations—Steam Calorifiers—Mixing Valves—Hot Water Calorifiers—Hot Water Gas Geysers—Gas Boilers—Materials—Boiler Explosions.**—A hot-water supply apparatus, to be considered satisfactory, should yield an adequate supply of hot water at all taps within a short time of the lighting of the fire—say, one hour. In addition, the fuel consumption should be moderate; provision made for shutting down and emptying the apparatus for the execution of repairs, cleaning out of boiler, &c.; the heat conserved by placing the pipes and storage vessels in warm positions, or by covering the same; and a reliable form of safety valve should be fitted to the boiler. Moreover, the size of the boiler and pipes, together with the storage vessel, should be properly proportioned. As it is seldom necessary to draw water off continuously, some means of storing the heated water is usually provided; closed storage vessels of a rectangular (tank) or circular (cylinder) form being mostly used, and connected to the boiler by "flow" and "return" pipes. The manner of connecting pipes to and from the storage vessel, and the position occupied by the latter varies, constituting what are known as different systems. There are, however, certain principles and essential details common to all systems:

(*a*) The boiler must be placed below the storage vessel.

(*b*) Boiler must be connected to storage vessel by two pipes, viz.:

Flow pipe, the lower end of which leaves the top of boiler, the other end terminating in the vessel about one-third the height of same from the top.

Return pipe. The lower end terminates near bottom of boiler; the other end at bottom of storage vessel.

These pipes must be given a rise towards the storage vessel of at least 1 in. in 10 ft.

(*c*) The cold water feed is connected either to the return pipe, boiler, or to the bottom of storage vessel, preferably the latter. It should be of ample diameter to ensure water entering the apparatus as fast as it is withdrawn, and a stopcock of the fullway type fitted thereon. The pipe should be connected in such a manner that convection currents cannot rise and set up "local circulation" therein; a simple method being to form a dip before the same enters the apparatus. It is a good plan to place a tee-piece or other fitting on the end of the supply pipe in storage vessel to spread the incoming water over the bottom of same, that the water may not readily push its way up to and mingle with the hottest water at top of storage vessel; at the same time the incoming water is prevented from taking a direct course to those pipes from which water is being drawn.

(*d*) An open pipe, or, as it is generally termed, "expansion or exhaust pipe," usually $\frac{1}{2}$ in. to 1 in. diameter, is taken off the top of storage vessel, whence it rises, terminating a short distance above the level of water in supply cistern. This pipe permits air to automatically pass out of the apparatus, and also prevents a "swelling-back" of water (much in excess of the actual expansion) into the supply cistern; the pipe also prevents, should the stopcock on supply be inadvertently closed, the apparatus being sealed and subjected to increased pressure. The end may be either just carried above and turned down to discharge into supply cistern, or may pass through a roof. The former is the most usual, and is generally satisfactory. Should the boiler, however, be of a powerful description, an ejection of steam and water may take place, filling the roof space with steam, and also heating the water in supply cistern. Should the pipe be taken through the roof, that portion containing water should, if possible, be kept inside to prevent freezing; failing this it should be well protected. The term "expansion pipe" is hardly a good one; water upon being heated expands about $\frac{1}{23}$ of its volume from 40° to 212° F., or boiling point; the increase due to expansion is gradually pushed through the supply pipe into the supply cistern, the capacity of which, measured above the water line when cold, should therefore be at least equal to $\frac{1}{23}$ the volume of water contained in the whole apparatus.

(*e*) Arrangement for Emptying: An emptying cock, with a loose key, to be used only in case of repairs—should be provided at the lowest part of the apparatus.

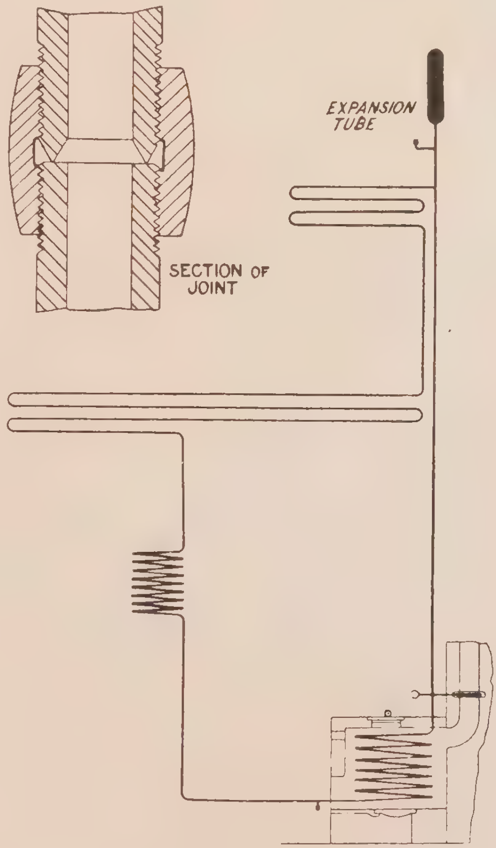


Fig. 1.—High Pressure System.

(*f*) Safety Valve: A good form of safety valve—preferably of the dead-weight type—should be connected direct to the boiler, and be periodically tested by lifting the spindle to ensure the valve is not stuck fast or choked.

(*g*) Draw-off Connections: Hot water

should—especially in the case of lavatory basins—be obtained immediately the tap is opened. As water will not circulate in single branch pipes, the length should be reduced as much as possible, either by carrying the main pipes in the direction of the fittings to be supplied, or by running branch circuits. The connection of branch circuits to main pipes and storage vessels is important, and it is as well to point out, that when a tap

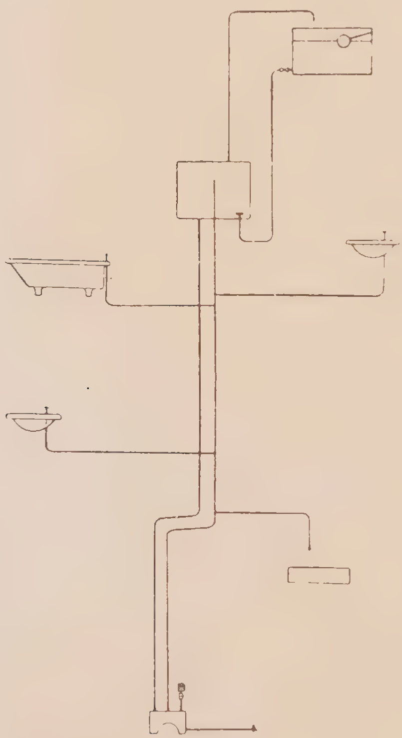


Fig. 2.—Tank System.

is opened on any pipe, water rushes to such tap from every possible source, hence, from the two ends of circuit branches; these branches should, therefore, terminate only where the hottest water is available.

Systems.—Tank Systems.—A tank—usually rectangular—is placed above the highest draw-off tap and connected to the boiler by flow and return pipes; an open pipe is taken off top of tank and the cold water supply brought in at bottom of same, all as heretofore detailed. Draw-off connections are taken from the flow pipe, or from a specially provided pipe connected to the tank at about the same level as the end of flow pipe therein. Connections are sometimes taken off the expansion pipe, which is a satisfactory arrangement, providing an outflow of water can be maintained; this, of course, depends upon the rate at which cold water enters the apparatus. Objections sometimes urged against the "tank system" are: (*a*) The placing of the storage vessel at some distance from boiler necessitates long flow and return pipes with consequent friction and loss of heat from the surfaces thereof.

(*b*) The tank is frequently placed in a cold position.

(*c*) When draw-off connections are taken from the main flow pipe, the tank may be emptied during failure of the water supply; the water in boiler may then evaporate and the boiler be burned and leak. An advantage of the tank system is that the placing of storage vessel above the taps ensures a good outflow of water to the highest taps, the water gravitating thereto until the water in tank is lowered to the level of the particular pipe supplying the tap. Should the draw-off tap, however, be on the main flow pipe, water will afterwards pass to the tap *viâ* the return pipe, being, of course, much colder. From what has already been stated with reference to "draw-off connections" a tap placed on the flow-pipe must always result in the issuing water being drawn from both the flow and return, although, owing to the force of gravitation and generally lesser friction, the bulk would be from the flow pipe so long as the upper end is immersed; hence, the arrangement is generally satisfactory.

Cylinder System. — A storage vessel—generally of cylindrical form to withstand the greater hydraulic pressure—is placed near to and just above the level of boiler, short flow and return pipes only being required. The open or expansion pipe is taken off top of cylinder and should travel in the direction of draw-off taps, which are then connected thereto, the pipe ultimately terminating above

the supply cistern as previously explained. To ensure the issue of the hottest water immediately a tap is opened, the water should circulate past the various taps, which may be done by returning the expansion pipe—after the last branch is passed—to the cylinder, connecting to the same about 6 in. from top, thus ensuring the hottest water only reaching the taps. The foregoing would be termed a "secondary circulation."

The cold water supply is connected to the bottom of cylinder and should be capable of ensuring a continuous flow of water at the taps. An emptying cock is also imperative.

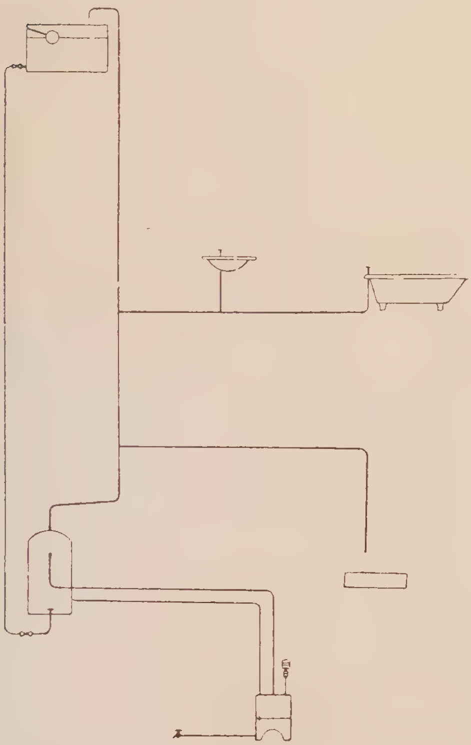


FIG. 3.—Cylinder System.

The advantages claimed for the cylinder system are:

(*a*) Short flow and return pipes between boiler and storage vessel, ensuring a quicker transference of heated water and reducing risk of freezing.

(*b*) As draw-off connections spring from the top of storage vessel the latter cannot be thereby emptied should the water supply fail.

(*c*) Cylinder is generally placed in a warmer position.

A fault often met with is a poor outflow of water to fittings placed just under the cold-water cistern, this being due in the first place to the low head of water, and secondly, to the water having to travel down to the cylinder and thence push, as it were, the hot water before it until the top is reached; hence in this respect the tank system possesses an advantage.

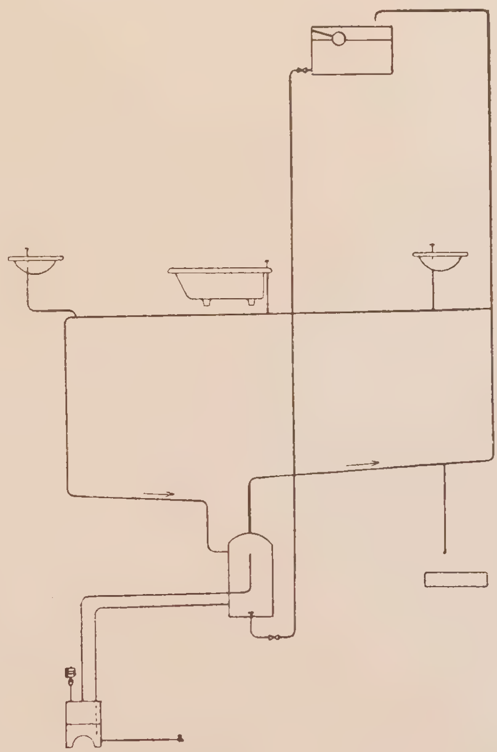


FIG. 4.—Cylinder System with Secondary Circulation.

COMBINED SYSTEMS.—A combination of the foregoing systems has the advantages of both and the disadvantages of neither.

This may be described as a cylinder system with secondary circulation, supplemented by a tank placed above the highest draw-off tap and connected to the cylinder system by disconnecting the highest part of the secondary

circulation and carrying the same up to and connecting to the bottom of tank, an open pipe being taken from top of tank. Draw-off connections may be taken from either the secondary flow or return; other return pipes may be taken from the bottom of tank to supply taps, and should be ultimately connected to cylinder near the top. The secondary flow pipe may stand up a short fire being made to suffice for cooking, hot water supply, and for warming the kitchen. More fuel, however, is required for cooking, &c., owing to a large quantity of heat being absorbed by the hot water apparatus; a further quantity is also lost by passing or escaping up the chimney, although this may be reduced by fixing a suitable but, at the same time, more expensive type of boiler. The efficiency

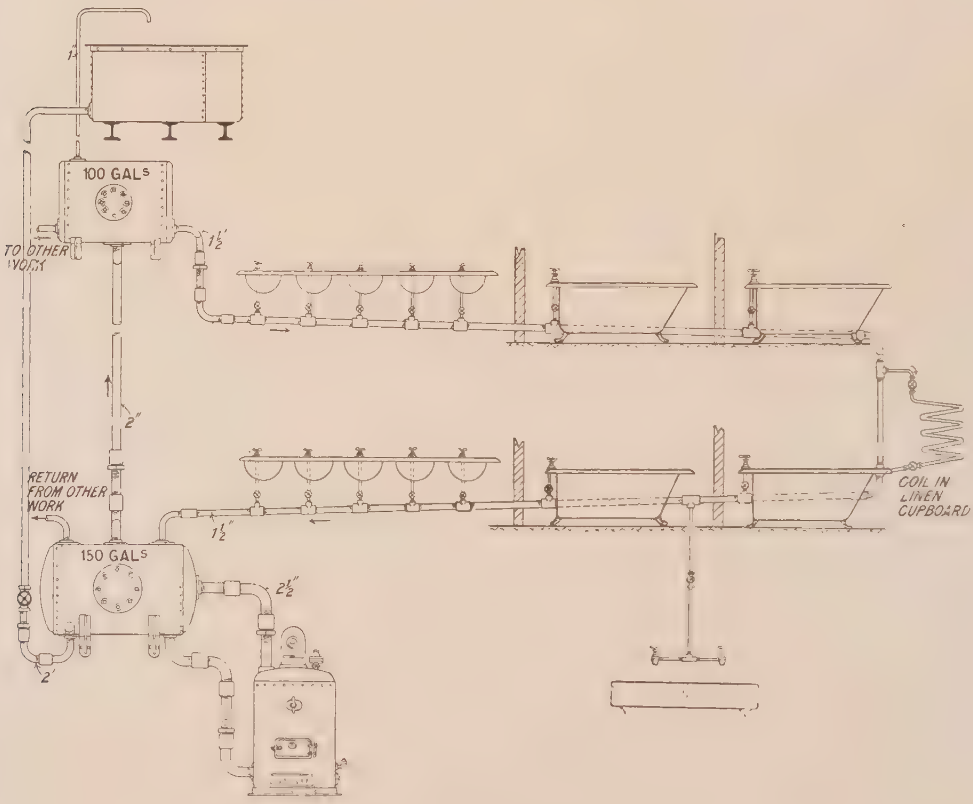


Fig. 5.—Combined System.

distance inside the tank, but a return pipe must leave the bottom to ensure through circulation. The combined capacity of the two storage vessels is not increased beyond that of other systems, and it is desirable to make the upper vessel about two-fifths of the required storage.

Boilers. — The most usual medium of obtaining a supply of hot water is by a boiler placed at the back of the kitchen range, one of range boilers is proportional to the area presented to the fire; for this reason "boot boilers" yield larger quantities of hot water by absorbing more flue heat than ordinary "bath boilers." The proportioning of boilers and storage vessels is very important, and although no hard and fast rule can be laid down, it is generally preferable to use small rather than large storage vessels, quicker results being obtainable. For ordinary

work the following proportions are satisfactory:—

Width of Boiler.	Shape.	Storage Vessel.	Flow and Return.	Number of Taps.
Inches.		Gallons.	Inches.	
9	Saddle	25	1	2 or 3
9	Boot	30	1	3 or 4
11	Saddle	30	1	,,
11	Boot	40	$1\frac{1}{4}$	4 or 5
12	Saddle	35	,,	,,
12	Boot	45	,,	,,
14	Saddle	40	,,	,,
14	Boot	50	,,	5 or 6

Independent Boilers.—The most economical arrangement for heating water is by means of independent boilers. These boilers are circular in form and connected in a similar manner to range boilers. The fire may be banked to last several hours, and practically any fuel may be burned therein. They are eminently suited for large houses, hotels and the like, in fact, wherever hot water in fairly large quantities is required at all times of the day.

Boilers and Incrustation.—Water containing lime in solution (temporary hard water) is apt to cause much trouble and expense by furring of the boiler and pipes. Heating such water to a temperature approaching boiling point removes the temporary hardness by expelling carbonic acid from the soluble calcic bicarbonate, and causing precipitation of the insoluble calcic carbonate, producing fur, which, unless removed from time to time, prevents the passage of heat to the water within the boiler, eventually causing destruction of the same by burning of the plates. The extent of fur formation depends upon: (*a*) the amount of lime in solution; (*b*) the quantity of fresh water passed through the boiler; and (*c*) the temperature of the latter; a variation in any one of which will bring about different results. All boilers used for temporary hard water should be provided with means of access and of a form to enable the interior to be freed from fur; hence, coil boilers and the like are quite unsuited for such purposes.

Steam Calorifiers or Heaters.—Where a steam supply is available the same may be usefully employed in warming water for domestic or supply purposes. These calorifiers may be powerful enough to heat the water as it passes through, or where the demand is large and intermittent a storage vessel may be coupled up to the same or a storage form of calorifier used instead. The connections to calorifiers and storage vessels,

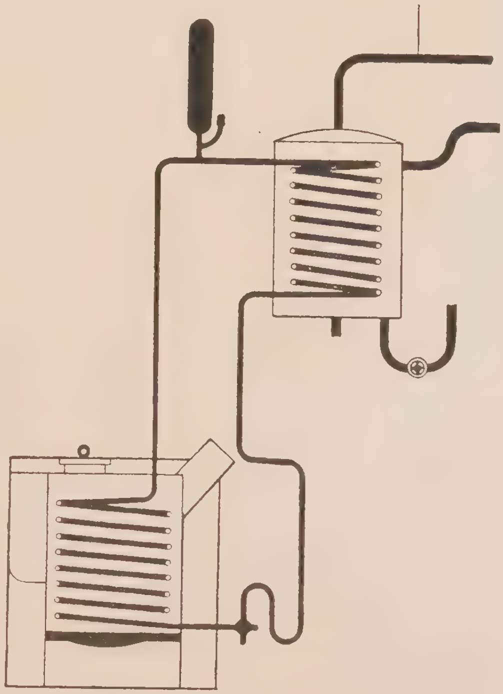


Fig. 6.—High Pressure Boiler and Coil for Indirect Supply.

and the arrangement of cold supply, expansion pipe, &c., is similar to the ordinary hot water apparatus. The efficiency of calorifiers, depends upon their form, the arrangement of tubes within, and the steam pressure. An automatic steam control valve to govern the temperature of water and prevent waste of steam is a desirable feature. A very efficient form of tube for use in calorifiers is an indented type (Row's patent) as may be seen from the following. "Relative heating value

of 1 sq. ft. of indented heating surface at various steam pressures (Row)":—

Steam in lbs. per sq. in.	5	10	15	20	25	30	40
Gallons of water raised from 50° to 180° F. in 1 hour	35	42	56	62	80	93	103

An allowance should be made for scaling up when hard water is used.

Mixing Valves. — Water is sometimes heated by the intermixing of steam and water

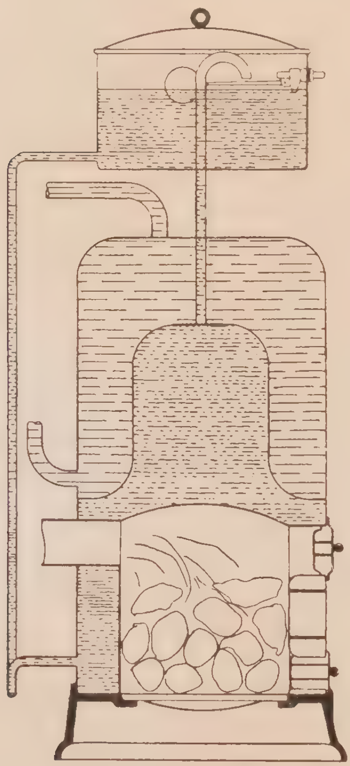


Fig. 7.—Section of Twin Boiler (Jones & Attwood's Patent).

in a valve as the water issues. These valves may be regulated to give water at any predetermined temperature. An objection sometimes urged against this arrangement is that a failure of the steam supply would enable steam to issue should the valve be opened. They certainly offer a convenient and cheap means of obtaining hot water, but where taps are scattered it would probably be more economical to use calorifiers. The use of live steam also entails the addition of fresh water to the boiler.

Hot Water Calorifiers.—Where water contains much lime in solution it may be preferable to heat the same by "indirect methods," *i.e.*, by means of a boiler connected to a coil or closed vessel placed inside a storage vessel, the water therein being heated by contact with the coil or closed vessel. The advantage of such an arrangement is that incrustation is avoided as the water in the boiler and coil, &c., is unchanged, whilst the water in the storage vessel is not heated to a temperature high enough to expel carbonic acid and cause fur formation. The primary heating apparatus may consist of an ordinary independent boiler with a coil or other arrangement connected thereto, or may be of a "high pressure" description. Obviously more heating surface will be required in the storage vessel than in the boiler; the surface of coil or heater in the vessel should be about five times the heating surface allowed in the boiler.

Hot Water Gas Geysers.—Hot water geysers are extensively used for supplying hot water for baths and lavatories, especially in flats, bungalows, and houses not possessing a hot water apparatus; they are also frequently fixed where a warm bath is required at an early hour. Geysers are generally constructed of copper—tinned inside—and possess a large heating surface over which the water flows, a continuous supply being furnished so long as gas is burning. The temperature of the issuing water will depend upon the rate at which the same passes through the geyser, the gas consumption remaining the same. In a good type of geyser, the gas should not have access to the water; an automatic valve to ensure that gas can only be burned whilst water is in or passing through the same should be fitted, and a flue pipe, not subject to "blow-down" provided; in fact, no geyser should be fitted without such a flue. A warm bath should, with gas at 3*s*. per 1,000 cu. ft., be obtained for about 1*d*.

Gas Boilers.—Gas boilers are frequently

used in place of and also to supplement range boilers. They are useful where a continuous supply is not required. When used to supplement an existing system the boiler is connected to the flow and return thereof by branch pipes. A flue is required with these boilers; a thermostatic valve to automatically lower the gas when the water has reached a predetermined temperature is a useful accessory.

Materials.—For temporary hard water, wrought iron galvanized is the most suitable material for pipes and storage vessels, the boiler being usually uncoated. Owing to the action of most soft waters on uncoated iron causing discoloration, or in the case of galvanized pipes, &c., dissolving the zinc coating, copper is to be preferred. The tubes should be thick enough for screwing and gun-metal fittings used throughout. It is often advisable to tin the threads and afterwards sweat the joints together. Copper pipes may be easily bent in the ordinary manner, unless sharp bends are required or the pipe is of a large diameter, when it may be filled with sand, resin or lead to prevent flattening. Pipe clips should be used and built into the wall to support and permit movement of the pipes; where passing through walls, floors, &c., metal sleeve pieces should be provided.

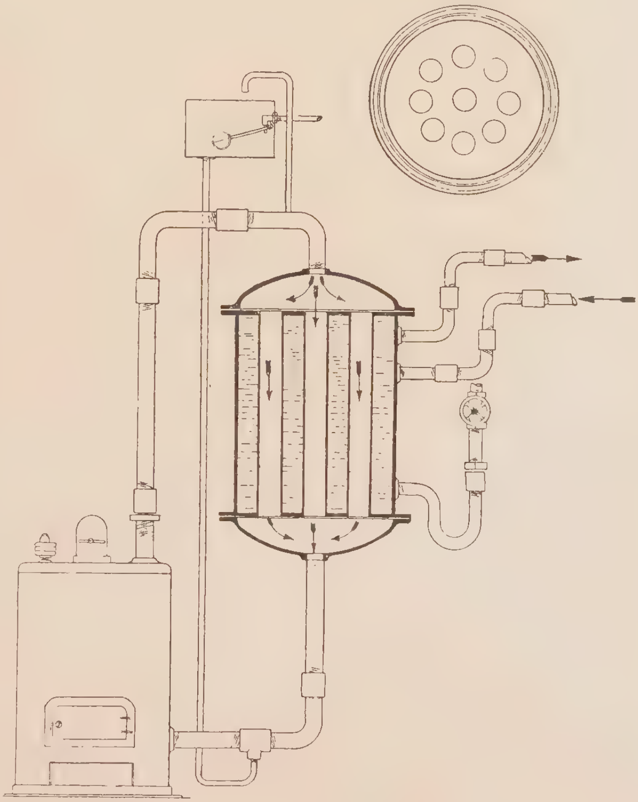


Fig. 8.—Hot Water Calorifier for Indirect Hot Water Supply.

Boiler Explosions.—Although the ordinary domestic boiler is of small dimensions, an explosion may be wrought with serious, if not fatal, consequences. The cause of domestic boiler explosions is frequently misunderstood. It may be stated that these explosions are invariably caused by a stoppage of the circulation pipes, and not through the entry of water into an empty red-hot boiler. A complete stoppage of the circulation pipes hermetically seals the water in the boiler; upon the application of heat the temperature is raised, and expansion of the contained water being prevented, an enormous pressure is created, which ultimately bursts the boiler. As an example of the enormous stored energy under these circumstances, 1 cu. ft. of water heated to exert 60 lbs. pressure per square inch amounts to about 300,000 foot pounds, or 350 times as much as an equal volume of steam at the same temperature. By far the largest number of explosions are due to pipes being choked with ice; it is seldom that an explosion is due to fur owing to the accumulation being gradual, and when nearly stopped a loud thumping noise gives ample warning. It will be at once obvious that the placing of stopcocks on flow and return pipes, especially in the absence of a safety-valve, is a dangerous

proceeding. It is popularly supposed that the entry of water into a red-hot boiler will burst the same, and is, in fact, the cause of

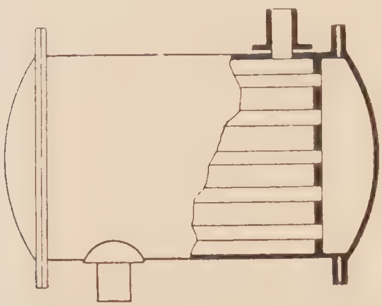


Fig. 9.—Horizontal Steam Water or Calorifier (Storage Pattern).

explosion. In the first place, some time would elapse before the whole of the water in the boiler was evaporated and further, should the water

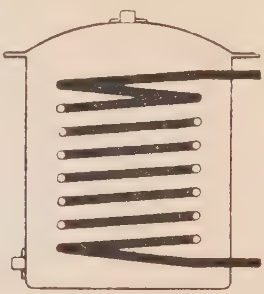


Fig. 10.—Steam Heater with Coil.

suddenly enter a red-hot boiler, the steam generated would force the water back until the steam pressure was released. It is possible that the boiler may be fractured, but nothing in the nature of a serious explosion would result. Very few people would, the writer believes, keep a fire in a range fitted with a boiler when no water was obtainable at the taps; in fact, the absence of water is usually taken as an indication that something is wrong. With circulation pipes choked with ice, however, no such warning is given; hence the importance of placing the pipes in warm positions or keeping the water warm. The writer knows of no instance where a domestic boiler explosion has occurred when a safety valve has been fitted direct to the boiler.

There are several other proprietary systems of "accelerated hot-water circulation." The advantages claimed for such systems are that smaller pipes may be used and the pipes run at any desired level; in many cases the boiler may be placed above the lowest radiators, an obvious advantage in many instances. Amongst such systems in successful operation may be mentioned "The Pulsial system of heating by low pressure hot water," erected by Messrs. Werner, Pfleiderer & Perkins, Ltd., Kingsway, London, W.C.; "Barker's Cable system of vacuum hot-water heating," erected by J. F. Phillips & Son, Old Queen St., Westminster; "The Reck system," designed by Captain Reck, of Copenhagen. In the foregoing systems, steam at, or about, atmospheric pressure is generated in the boiler. Another system is to install a motor or steam-driven pump on the circulation pipes near the boiler, hot water being pumped through the apparatus. W. F.

House Refuse.—(*See* "Refuse Disposal.")

"**Howatson Process**" of Sewage Purification.—This system has been tried at

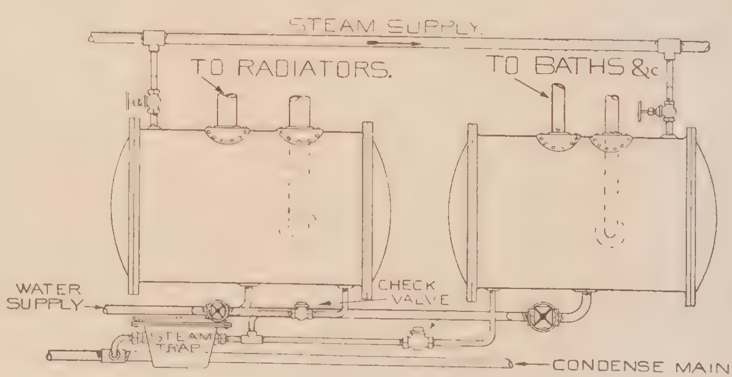


Fig. 11.—Arrangement of Steam Calorifiers for Warming of Hot Water Supply.

Middelkerke, Wenduyne, Haeren, and elsewhere. It has also been satisfactorily applied to the purification of drinking water at Ostend, Haeren, and other places. Peroxide of chlorine is used as a sterilising agent, and this is obtained by the decomposition of chlorate of potash by sulphuric acid. The organic matter in the sewage is rapidly oxidised by the soluble gas thus produced, and a high degree of purification is obtainable.

Hydraulic Gradient.—(*See* "FLOW IN PIPES AND CONDUITS.")

Hydraulic Mean Depth.—(*See* "FLOW IN PIPES AND CONDUITS.")

Hydrolytic Tank.—The first tank of this type was installed at Hampton-on-Thames in 1903. The novel design and the special mode of operation implied so complete a departure from the usual methods of construction and of practice that more than ordinary thought and time were devoted to its consideration. The principles of its action are as follows:—

(1) The rapid separation of the main volume (80 to 90%) of the liquid from the remaining part of the sewage.

(2) The exclusion of this proportion from any contact with the resulting sludge, from the presence of the generated gases, and from any but the shortest tank operation.

(3) The concentration of the suspended impurities in the smaller volume (10 to 20%) of the sewage.

(4) The continuous removal of this volume from the sedimentation chambers by its downward displacement into a separate chamber, where the suspended matters are deposited.

(5) The correction of the periodical outflow of suspended matter, the result of the gaseous disturbances, by the re-deposition and removal of these solids in an additional chamber.

(6) The limitation of the hostile forces of sedimentation and gaseous eruptions to separate chambers.

(7) The submission of the whole of the sewage to the attracting influence of self-cleansing surfaces, in order to abstract as large a proportion of the finer suspended and colloidal solids as possible.

(8) The prevention of any undue accumulation of scum and of sludge by periodically withdrawing the excess; and

(9) The continued maintenance of the working capacities of the several chambers.

The following description, together with the drawings of the Hampton tank, will demonstrate how these principles are carried out. The sewage having passed through a $\frac{1}{2}$ in. mesh screen enters one of two detritus tanks. These have a capacity of 3,000 gallons each, or one-eightieth of the present daily flow of sewage, and are worked alternately, the sewage being diverted from one to the other every fortnight. The sludge is removed from the full tank by means of a valved opening, through which it passes to the sludge manhole. In this way nearly one-half of the total quantity of sludge is removed from the sewage. The sewage leaving the detritus tank enters the centre of a transverse channel, which conveys it into the sedimentation chambers of the hydrolytic tank by delivering it behind submerged walls. The tank is divided by light walls into three compartments, the centre one of which is the reduction chamber, the outer two being the sedimentation chambers. The only means of liquid communication between these compartments are the narrow openings at the bottom of the sedimentation chambers. At the end of the tank is a weir divided into three portions, one for each chamber; the relative widths of these divisions govern the outflow of sewage from the several chambers and determine the proportional quantity which flows through each. The side weirs (sedimentation) have a width of 7 ft. each, or a combined width of 14 ft., and the central (reduction) weir has a width of 2 ft. The total width of 16 ft. is, therefore, apportioned so as to permit of 87·5% of the sewage passing along the sedimentation chambers and over their weirs, whilst ensuring that

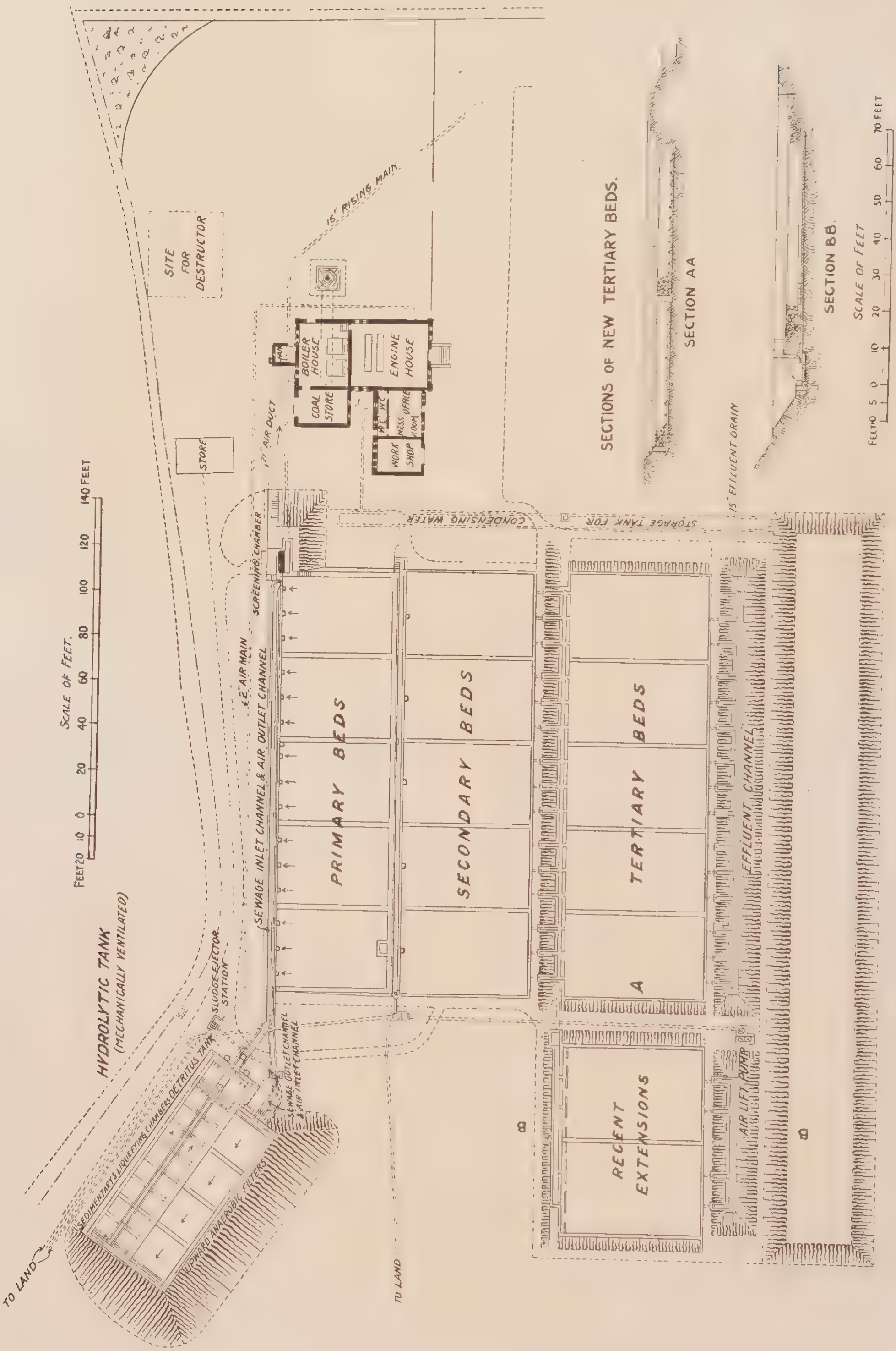


FIG. 1.—Plan of Hydrolytic Tank, with Sections of Beds, Hampton.

12·5 % of that liquid shall pass out of the bottoms of them into the reduction chamber and over its weir. The entire volume of sewage enters the sedimentation chambers. Of this volume 87·5 % travels along a practically level plane, while the lighter and heavier particles describe upward and downward curves, the length of the curve being proportioned to the weight of the particle and to the velocity of the flow. The lighter particles rise to the surface, and are retained there by the submerged walls at the end of the chamber. The heavier particles in falling have their curve shortened by the descending volume (12·5 %) of the liquid which passes out of the bottom of the sedimentation chambers into the reduction chamber; in other words, the natural downward displacement of the particles are accelerated by the downward flow of one-eighth of the entire volume of sewage, by which means the deposit is carried into the reduction chamber. The slower rate of flow in this chamber permits the solids to descend into the lower part of the chamber, and prevents so large a quantity of the deposited matters from being carried out of the tank during periods of agitation caused by the gases generated. The formation of gases is, with almost negligible exceptions, limited to the reduction chamber. The rising gases in the reduction chamber are separated by the sloping walls from the depositing solids in the sedimentation chambers, and thus the confusion in operation which would otherwise ensue is obviated. The part of the chamber below the openings at the bottom of the sedimentary chambers is for the reception of sludge; it is designed to hold the sludge contained in 40 days' average flow of sewage. In actual work, however, it holds double this quantity. Along the floor at intervals valves are fixed, through which 3,000 gallons of sludge are removed from the tank about once a fortnight into the sludge manhole. Floating solids on the surface of the liquid in the sedimentary chambers, and those floated in the reduction chamber, are occasionally, when unduly accumulating, raked over into the empty detritus tank. The sewage flowing over the weirs enters a channel which leads to the four hydrolysing chambers, which are arranged

	Parts per 100,000.								
	Solids.		Colloids in Solution.	Chlorine.	Nitrogen.				Oxygen.
	In Suspension.	In Solution.			Ammoniacal.	Albuminoid.	Nitrous.	Nitric.	Absorption 4 Hours.
Crude Sewage . .	45·6	103·9	23 0	16·4	8·25	1·46	nil	nil	9·6
Hydrolytic Tank Effluent	3·7	99·8	23·0	16·1	7·90	0·48	nil	nil	6·4
Percentage Reduction	92	—	—	—	—	67	—	—	33

in sequence. The liquid is conducted to the bottom of each chamber and passes upwards through the material to the surface, where it flows over a weir and descends to the lower part of the next chamber. After the operation

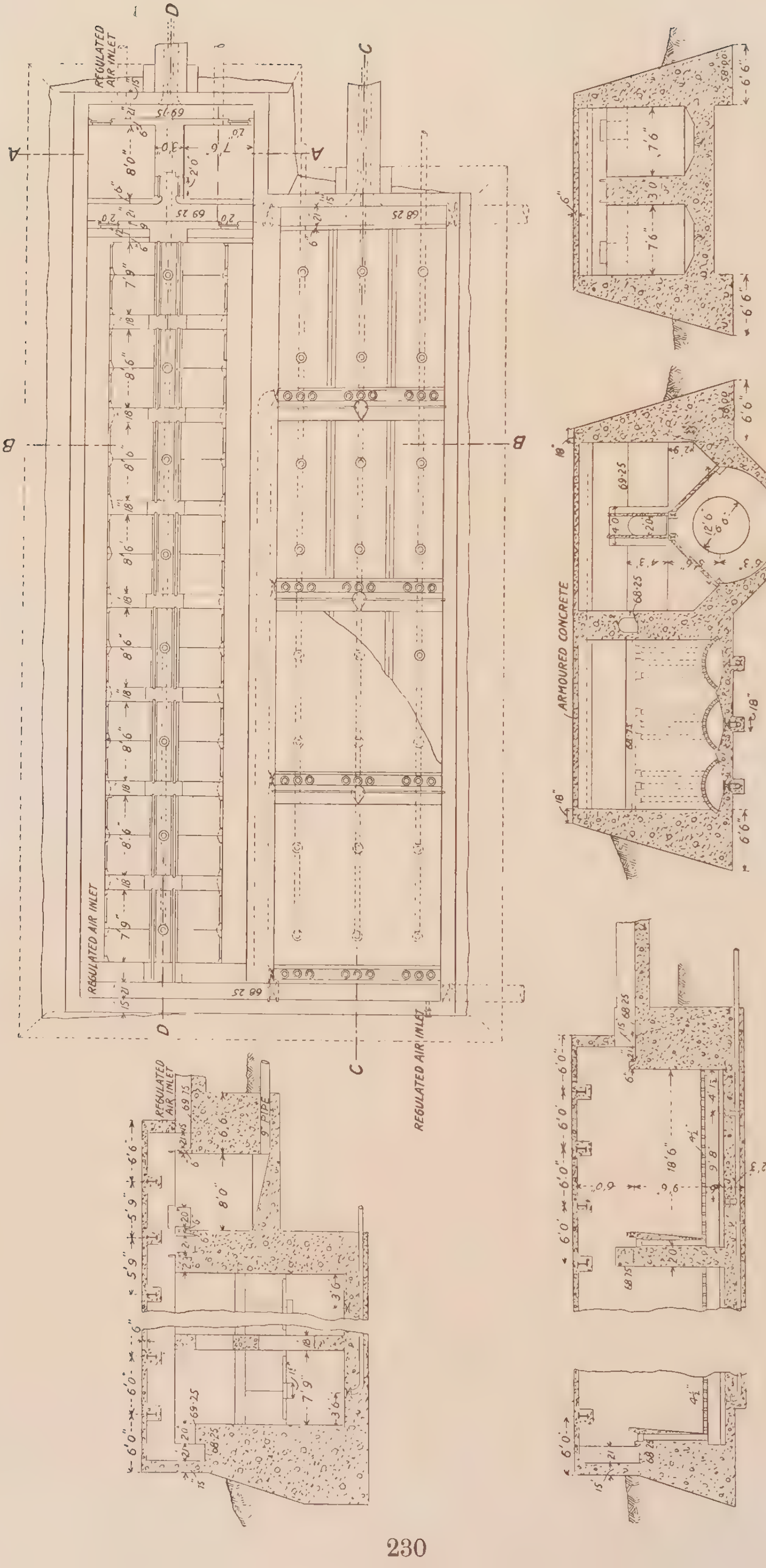


FIG. 2.—Hydrolytic Tank, Plan and Sections of Details.

has been repeated in the four chambers the liquid enters the channel which conducts it to the contact beds. Tank and channels are mechanically ventilated, and the withdrawn gases are purified before being discharged into the atmosphere. The sludge is conveyed into trenches in the land and is almost immediately covered over with earth. Five years' uninterrupted experience has demonstrated the practical value of the hydrolytic tank as a highly efficient means of removing the suspended matters from sewage, for collecting the sludge, and for admitting of the maximum withdrawal of these matters during the continuous work of the tank.

S. H. C.

Hydraulic Memoranda.—The following brief hydraulic notes and memoranda will be found convenient for reference by readers of this work and for engineering calculations generally:—

WATER, EQUIVALENTS, &c.

One Imperial gallon = 277·463 cu. in.
,, ,, ,, = ·16 cu. ft.
,, ,, ,, = 10·00 lbs. avoirdupois at 62° F.
,, ,, ,, = 4·546 litres.
One United States gallon = 231 cu. in.
,, ,, ,, ,, = 8·33111 lbs.
One cubic foot of water = 6·23 imperial gallons.
,, ,, ,, = 7·480519 United States gallons.
,, ,, ,, = 62·28 lbs.
,, ,, ,, = ·55606 cwt.
,, ,, ,, = ·0278 ton.
,, ,, ,, = 28·3116 litres.
,, ,, ,, = ·0283 cu. metre.
One cubic inch of water = 252·286 grains.
,, ,, ,, = ·03604 lb.
One pound of water = ·10 Imperial gallon.
,, ,, ,, = 27·74 cu. in.
One ton of water = 224 Imperial gallons.
One litre of water = ·22 Imperial gallon.
One cubic metre of water = 220 Imperial gallons.
One cubic metre of water = 1 ton (approximately).
One kilo. of water = 2·2046 lbs.

PRESSURE, HEAD, &c.

Head in feet × ·4335 = pressure in lbs. per square inch.
Head in feet × ·341 = pressure in lbs. per circular inch.
Head in feet × 62·425 = pressure in lbs. per square foot.
Pressure in lbs. per square inch × 2·306 = Head in feet.
Pressure in lbs. per square foot × ·016 = Head in feet.
A pressure of 1 lb. per square inch = column of water 2·31219 ft. high.
A column of water 1 ft. high = a pressure of ·4325 lbs. per square inch.

PIPES, DISCHARGE, &c.

Gallons contained per foot run of pipe = (diameter in inches) ^{2} × ·034.
Lbs. per foot run of pipe = (diameter in inches) ^{2} × ·34.
Doubling the diameter of a pipe increases its capacity four times.
Discharge varies as the square root of the "head."
Cubic feet of water per minute × 9,000 = gallons per 24 hours.
The friction of liquids in pipes increases as the square of the velocity.

RAINFALL.

Average rainfall for England is usually taken at 30 in. per annum.
One inch of rain over 100 sq. ft. of surface yields 52 gallons.
One inch of rain over an acre of surface = 100 tons of water (approximately).
One inch of rain over an acre of surface = 3,630 cu. ft. of water.
One inch of rain over an acre of surface = 22,650 gallons.
Rainfall in inches × ·52 = gallons per squar foot.

Rainfall in inches × 2,323,200 = cubic feet per square mile.

Rainfall in inches × $14\frac{1}{2}$ = millions of gallons per square mile.

Evaporation.—The annual amount of evaporation is very variable according to circumstances. On land surfaces in this country it varies from 8 in. to 20 in. On large water surfaces at Lea Bridge it was found to be about 21 in. per annum, but, in many cases, the amount of evaporation from large water areas is equal to the rainfall.

Horse-power.—The horse-power required to raise a given quantity of water in gallons to a given height is found as follows:—Multiply the water to be raised in gallons per minute by 10 and by the height the water has to be raised in feet, and divide the product by 33,000. To the net horse-power thus obtained must be added an allowance to cover friction and "slip," according to the necessities of the case. An addition of at least one-third is usually made.

Another rule is as follows:—

Actual horse-power = $\cdot 0023\, H\, Q$.

Where Q = quantity of water raised per minute in cubic feet.

Where H = height in feet.

Contents of wells or cylinders in gallons per foot of depth or length:—Diameter in feet squared × 4·9 (approximate).

Equivalent Pipes.—To find how many pipes of smaller diameter are required to discharge the same quantity as one large pipe:—

$$\text{Number of pipes required} = \frac{\sqrt{D^5}}{\sqrt{p^5}}.$$

Where D = diameter of large pipe in inches.

Where p = diameter of small pipe in inches.

Distribution of Water.—In determining sizes of distributing mains a main room should be provided capable of yielding the maximum discharge with an expenditure of head in overcoming friction not exceeding 25 % of the available statical head. For moderately large pipes 3 ft. per second is generally regarded as a suitable rate of flow. The maximum rate of draught upon water mains may be from two to two-and-a-half times the average consumption during the 24 hours. The maximum statical head upon water mains should not exceed 200 ft., or about 86 lbs. per square inch; and for an effective supply should not, if possible, be less than 100 ft. It is more advantageous to have ample main room than to rely upon excessive statical head as, upon occasions of heavy draught, the "head" will be rapidly absorbed in overcoming frictional resistance in the mains. Turning valves on and off too suddenly leads to concussion and "hammer," and may burst a main.

Hydraulic Ram.—The hydraulic ram is a machine which is largely used for the purpose of raising water to a height considerably above the top of the "fall" or head available as motive power. In other words, the apparatus utilises the momentum of a stream of water falling through a small height in order to lift a portion of that water to a greater height. Thus 100 gallons of water falling through 10 ft. would raise 10 gallons to a height of 80 ft., or, 100 gallons falling 5 ft. would raise 1 gallon to an elevation of some 300 ft. The mechanism of the hydraulic ram is designed to take advantage of the "ramming" force, or momentum of the flow of water in a pipe when suddenly arrested. The outline diagram (Fig. 1) illustrates the general arrangement of the different parts of a system for raising water by means of a hydraulic ram. The water from the source of supply flows down a "drive-pipe" of considerable length, and with the requisite "fall" to work the ram; when the water approaches its maximum velocity at the ram its flow is suddenly and automatically checked, the momentum thus producing a rise of pressure within the ram which closes the "waste outlet valve" and forces a part of the water through the "delivery valve" into the "air vessel" and "delivery main." The height to which the water is thus delivered depends upon the amount of fall available.

Under ordinary circumstances it may be said that the hydraulic ram returns about 50 % of the natural effect, or, in other words, the quantity of water raised multiplied by the height of the delivery above the ram will be about 50 % of the quantity of water working the ram multiplied by the "fall," in the same unit of time. It is very generally estimated that one-seventh of the water can be raised to about four times the head of supply, or one-fourteenth eight times, or one twenty-eighth sixteen times, thus giving a useful effect of about 57 %. Various improvements have been introduced during recent years by ram makers in regard to economy of drive water and other matters, and in the Bailey's Decœur's hydraulic ram one-third of the drive water is forced to two-and-a-half times the height of fall, one-sixth to five times the fall, or one-tenth to eight times the fall, giving a return of about 83 % of the natural effect. In determining the size of ram suited to any particular case, it will be necessary to ascertain the fall in feet available from the source of supply to the site of the ram, the height to which the water is to be raised, the horizontal distance from the source of supply to the place of delivery, and the quantity of water required to be lifted per hour or day. If the source of supply is limited, then the flow should be accurately gauged to ascertain the yield in gallons per minute. An approximate idea of the quantity of water which should be available at the source of supply for the purpose of working small and medium-sized rams may be gained from the fact that for every gallon raised some 8 to 12 gallons must pass through the ram. Larger sizes raising water to high elevations with comparatively low falls consume, proportionately, more water in working. The quantity of driving water required to work a ram will depend, therefore, upon the amount of working fall available, the height to which the water is to be raised, and the quantity of water to be raised. Under suitable conditions rams can be worked with less than 1 gallon of water per minute. The diameter of the fall or injection pipe in hydraulic rams is very generally about twice that of the delivery or rising main. The length of the supply pipe may be made from five times to ten times the height of the "fall." Any working fall from about 18 in. up to 100 ft. will work a ram, but the greater the fall obtained up to about one-third of the total height the water has to be raised above the ram, the more economical will be the result, *i.e.*, the ram will cost less to raise a given quantity and less driving water will be required. Where a dam cannot be formed across a stream, the requisite fall may be got by carrying the driving water the requisite distance down the stream by means of stoneware pipes running nearly level until the necessary fall is gained, but where the driving water is plentiful a small working fall will suffice with a more powerful ram, and

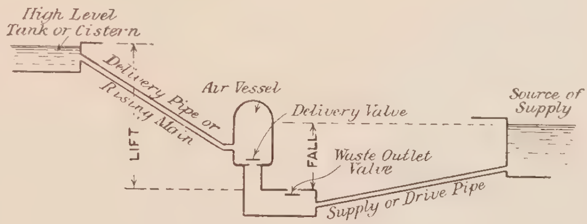


Diagram showing arrangement of Hydraulic Ram.

may be found cheaper than obtaining a greater fall and using a small ram. Rams will force to a distance of several miles, some firms guaranteeing as much as 10 miles; and, with a sufficient driving water and working fall will force to any height up to 1,000 ft. As one instance of a high lift may be cited that of a pair of Blake's rams worked by impure stream water, with a fall of only 9 ft., raising 4,500 gallons of spring water per day to a height of 719 ft. above the rams (*i.e.*, about eighty times the height of the working fall), and to a distance of 1,223 yards for the supply of a large horse stud farm. The height to force is calculated from the level of the ram or bottom of the working fall. The usefulness of hydraulic rams has been very greatly extended by the introduction of those forms in which the water for the motive power is obtained from one

source, and that raised for use from another. This is accomplished by the introduction of a cylinder and piston, with the necessary valves, between the working-barrel or main pipe of the ram and the delivery pipe.

A hydraulic ram should be simple and strong in design, as, when fixed, very little attention is usually given, the apparatus frequently being left for months at a time. The air chamber should be of tested strength, all joints faced, and all valves, such as delivery, beat, and snifting valves, should be made of gun metal. The apparatus is a very useful and economical one in some circumstances, will work even when flooded with water, and requires no lubrication or packing and very little attention.

The action of the hydraulic ram is somewhat violent and noisy, and the wear and tear necessarily considerable. These objections are largely overcome by the hydraulic pressure pump, by means of which a large quantity of water under a small head, flowing slowly through a supply pipe, is made to steadily raise a portion of the water to a higher level. The apparatus consists generally of a large piston working vertically in a cylinder surmounted by a small upper cylinder, in which works a hollow plunger delivering into an air vessel from which the delivery pipe, or rising main, is taken off in the same manner as in the case of the hydraulic ram. Where duplicate cylinders are provided the apparatus can be made to deliver water steadily and continuously.

Hydrogel.—(*See* "Colloidal Matters.")

Hydro - Pneumatic Systems. — (*See* "Ejector.")

Hydrosal.—(*See* "Colloidal Matters.")

Hydrostatic Head.—The pressure due to the weight of liquids, when they are confined, is proportional to the height of the column, and is equally exerted in all directions. Any vessel which contains a liquid has, therefore, to sustain upon each point a pressure, the intensity of which will vary according to the height or head of the liquid above that point, but which will, otherwise, be quite independent of the shape of the vessel. As an instance, suppose a closed tank with a pipe projecting vertically from its top and that both are filled with water; the intensity of the pressure upon the bottom of the tank will be proportional to the height of the tank plus that of the pipe. Again, suppose this arrangement inverted, with the end of the pipe closed; the pressure per square inch or per square foot, as the case may be, will, at the bottom of the pipe, be precisely as it was at the bottom of the tank when in its former position. The large "body" of water in the tank does not, as so many people suppose, make any difference whatever to the intensity.

From this it follows that the pressure per square inch, for example, will be equal to the head in inches multiplied by the weight of a cubic inch of the liquid—the same, of course, applies to any other unit of measurement. (*See article on* "Hydraulic Memoranda.")

E. L. B.

Hygiene and Public Health. — **Definition—Preventive Medicine—Sanitary Code and Administration — Medical Officer of Health —Acts of Parliament — Bye-Laws.** — Hygiene is defined as the science which teaches us how to keep the body in health; but it would be more exact to define it as embracing the application to this end of a whole group of sciences which throw light on the growth, development, and vital activities of man. It aims at rendering growth more perfect, life more vigorous, decay less rapid, and death more remote. The principles involved and the scope of the field of study necessarily embrace every circumstance which affects, for good or evil, man's physical welfare; or in other words all those factors, personal and environmental, that determine perfect health. It is not possible here to fully enunciate those principles; the object and

scope of hygiene and public health can only be broadly defined. The importance of the subject from the standpoints both of the individual and the State, cannot well be exaggerated, for it seeks to promote that physical health which determines in such large measure the happiness and productiveness of the individual. The value of the observance of the laws of hygiene are, from the communal standpoint, largely economic; nothing, for instance, is so costly as disease, and just as the employer of labour gains, both in the quantity and quality of work performed, by paying due regard to the sanitary environment of his workers, so does the State reap a material benefit by promoting wise public health legislation, that physical efficiency which, while promoting moral and mental health, also increases that vigour and productiveness of the community which determine national prosperity. Seeing, then, that it is a prime matter of State concern that the public health should be conserved, and recognising that the individual is often ignorant or helpless in these respects, the State has sought to promote the general health by public health legislation and to provide the necessary machinery to give it effect.

Preventive Medicine.—Hygiene is essentially preventive medicine, but it also embraces matters which are beyond the province of medicine. A convenient subdivision of this great subject may be made into (1) General and personal hygiene; (2) Special hygiene; (3) Public health. General hygiene embraces those external or environmental conditions of locality, site, dwelling, air, water-supply, soil, refuse and sewage disposal, &c., which determine healthy life; while measures which relate more particularly to the individual's person, and are so largely dependent upon individual habits and initiative for their observance, are included in the sphere of personal hygiene. Thus bathing, washing, clothing, food and diet, exercise, &c., are matters of personal hygiene. Special hygiene embraces the hygiene of special circumstances, as, for instance, school hygiene, industrial hygiene, military, naval, and tropical hygiene. Public health in the sense of State hygiene may be taken to embrace the legal provisions and the administrative measures which are designed to protect the health interest of the community, such as the prevention of the spread of infectious disease, the prevention of unwholesome conditions in the community, the protection of the public water and food supply, and generally the removal of nuisances which, by favouring the prevalence of disease, may act as foci of infection to the community. Much remarkable testimony is forthcoming to the benefits which have accrued from the application of the laws of hygiene; as, for instance, the great reduction in sickness and mortality among sailors in our navy, among the soldiers in our army, among the prisoners in our gaols, and the occupants of our hospitals, factories, workshops, &c.; and the effect of the growth of public health legislation and administration and of an increasing realisation by the people of the importance of the demands of sanitation, is shown by the reduced death-rate from all causes and from certain special diseases (more particularly certain communicable diseases); while the increase in the mean duration of life of all classes is no less noteworthy. If it is conceded that the observation of the laws of hygiene leads to the survival of some who would otherwise have succumbed as the result of the law of the survival of the fittest, then it must be conceded also that preventable disease does not kill only; too often it maims or enfeebles; so that in a substantial—perhaps in a very large—proportion of cases it subtracts the patients whom it may ultimately spare from the sum of the vigorous and adds them to the sum of the relatively inefficient.

Sanitary Code and Administration.—It may be said that no other country possesses a sanitary code and administration so complete as that of Great Britain. The provision for public health administration in this country includes the Local Government Board (a central authority directly under Government),

county councils, borough councils, urban and rural sanitary authorities, and their respective staffs of officials. The Local Government Board is charged with some measure of control and supervision of Poor Law and Public Health Administration (including vaccination) throughout the country. For these purposes a large staff of skilled advisers and inspectors has been appointed, and a National Vaccine Establishment for the supply of vaccine-lymph is maintained. The more important powers and duties of the Local Government Board may be summarised as follows: To issue regulations and instructions with reference to the prevention and suppression of epidemic disease; to inspect vaccination; to regulate the borrowing powers of local authorities, by inquiring into projects of sanitary improvement relative to housing of the poor, sewage disposal, water-supply, hospitals, &c., when the projects involve the raising of a loan for their undertaking; to revise and approve local sanitary bye-laws; to sanction or veto the appointment of local sanitary officials, when the State pays a moiety of the salaries of such officers. The Home Office deals with the conditions of labour in factories and workshops, &c., and possesses a staff of inspectors charged with many duties under the provisions of the Factory and Workshops Acts, &c., and the Orders issued from time to time. County councils supervise generally the sanitary administration throughout the county, and may report a defaulting sanitary authority to the Local Government Board. They are also given certain administrative powers in reference to public health matters; they are, for instance, charged with the administration of several important public health measures, namely, the Rivers Pollution Prevention Act, the Education Act, the Midwives Act, the Isolation Hospitals Act, the Contagious Diseases Animals Acts, 1878 to 1886. The several sanitary areas comprised within the county are constituted either boroughs, urban or rural sanitary districts; and the borough or district councils are charged with the local administration of the bulk of public health legislation. To assist in the satisfactory performance of these duties a clerk, a medical officer of health, a surveyor, and one or more sanitary inspectors are appointed to serve each local authority.

Medical Officer of Health. — The duties of the medical officer of health, as defined by the Local Government Board, require that he shall inform himself respecting all influences which may injuriously affect the public health in his district, and advise the sanitary authority thereon; that he shall investigate, report and advise upon outbreaks of contagious, infectious, or epidemic disease, and give immediate information to the Local Government Board and county council of any outbreak of dangerous infectious disease; that he shall deal with unsound food, offensive trades, &c., and shall furnish an annual report; subject to the instructions of the sanitary authority he shall direct or superintend the work of the sanitary inspector. The duties of a sanitary inspector relate to the inspection of nuisances, of offensive trades, food, &c.; the procuring of samples under the Sale of Foods and Drugs Acts, and the taking of measures, under the direction of the medical officer of health, for preventing the spread of dangerous infectious disease.

Acts of Parliament.—The chief Acts of Parliament which have reference to the public health embrace measures to guard the health interests of all classes of the community, from the cradle to the grave. Indeed the practical realisation of the true scope of preventive medicine is one of interesting evolution. Preventive medicine at first took cognizance of little else than dangerous infectious disease and prescribed certain measures of precaution almost exclusively when these diseases reached epidemic proportions. Then followed the adoption of measures directed towards ensuring an improved sanitary environment for the people. These mainly related to the drainage arrangements and water supply; in fact, at first they went little further, and it is only comparatively recently that the

fuller needs of hygienic environment began to receive the attention their importance demands. Personal hygiene remained relatively neglected for what were conceived to be the superior claims of sanitary environment; but when the broader horizon of preventive medicine was illumined by a truer conception of its scope and demands, it was recognised that the personal and social circumstances of the community were at the root of the main difficulties with which preventive medicine had to contend. The fact is now generally appreciated that the hygienic well-being of the community will be determined more by education and training, developing individual desire and initiative, than by legal enactment.

While therefore we possess in several Public Health Acts the power which enables administrative bodies to provide the sanitary environment of the individual, whether at home or in the workshop or factory, legal measures have more recently appeared upon the statute book which mainly concern themselves with the personal demands of hygiene.

It is only possible here to schedule the more important legal enactments which are embraced in the public health legislation of this country. They are as follows: The Public Health Acts of England and Wales, London, Scotland, and Ireland—including certain Public Health Amendment Acts, the more recent of which is the Amendment Act of 1907. These Acts contain provisions dealing with conditions which are nuisances or injurious to health, offensive trades, water supply, house drainage, sewerage and sewage disposal, scavenging and cleansing, houses let in lodgings, common lodging-houses, underground rooms, unsound food, slaughter-houses, dangerous infectious diseases, and disinfection.

The Local Government Acts, 1888, 1894.

The Midwives Act, 1902.

The Births and Deaths Registration Act, 1874.

The Notification of Births Act, 1907.

The Infant Life Protection Act, 1897.

The Education (Administrative Provisions) Act, 1907.

The Employment of Children Act, 1903.

The Provision for Meals for Children Attending Public Elementary Schools Act, 1906.

The Prevention of Cruelty to Children Act, 1894.

The Children's Act, 1908.

The Shop Hours' Acts, 1886, 1892, 1904.

The Factories and Workshops Acts, 1891, 1895, 1907.

The Alkali, etc., Works Regulation Act, 1881, 1892.

The White Phosphorous Matches Prohibition Act, 1908.

The Housing of the Working Classes Acts, 1890, 1900, 1903.

The Customs and Inland Revenue Act, 1890, 1903.

The Open Spaces Acts, 1887, 1890.

The Infectious Disease Notification Acts, 1889 and 1899.

The Infectious Diseases Prevention Act, 1890.

The Isolation Hospitals Act, 1893.

The Vaccination Acts, 1867, 1871, 1898, 1907.

The Cleansing of Persons Act, 1897.

The Aliens Act, 1905.

The Inebriates Act, 1898.

The Public Health (Interments) Act, 1879.

The Burial Acts, 1854, 1855, 1857.

The Cremation Act, 1902.

The Public Health Water Act, 1878.

The Rivers Pollution Prevention Acts, 1876, 1893.

The Canal Boats Acts, 1877, 1884.

The Sale of Foods and Drugs Acts, 1875 to 1899.

The Sale of Horseflesh Act, 1889.

The Margarine Act, 1887.

The Butter and Margarine Act, 1907.

The Public Health (Regulations as to Food) Act, 1907.

In addition there are in force many orders, bye-laws and regulations which are authorised by Acts of Parliament. The more important orders are the Dairies, Cowsheds and Milkshops

Orders of the Local Government Board, 1885, 1899, and several orders issued by the Home Office relating to factories and workshops. Among the regulations issued by the Local Government Board special mention should be made of those designed to prevent the importation of cholera, yellow fever, and plague into these islands, and those relating to canal boats, and to the importation of unsound food and foreign meat; while among the regulations which local sanitary authorities are empowered to make, those relating to dairies, cowsheds, and milkshops, and the removal to and the detention in hospital of infectious patients removed from ships and vessels, are of special importance.

Bye-laws.—Subject to the approval of the Local Government Board many bye-laws are authorised to be made by local sanitary authorities, and to assist those bodies in framing such bye-laws the Board has issued a series of model bye-laws. Bye-laws may be made dealing with houses let in lodgings, offensive trades, common lodging houses, new buildings, slaughter-houses, cleansing and scavenging, the prevention of certain nuisances, mortuaries, &c.

Finally, the public health legislation of this country includes many local improvement Acts which only relate to the particular district for which the special powers have been sought and obtained. These Acts are now numerous, and they constitute an important addition to the sanitary legislation of the country. As instances of such Acts, the London County Councils General Power Acts and the Sheffield Corporation Act, 1903, for the compulsory notification of consumption in that city, may be cited. H. R. K.

Incandescent Lamps.—(*See* "Electricity" and "Gas.")

Indicator.—The Expansive Use of Steam—Condensing.—All good class modern steam pumping machinery must be designed and worked with a careful regard to fuel economy, and smallness of steam consumption of the engines. To this end the tendency for many years has been towards the employment of high-pressure steam, used expansively in either two, three, or four stage compound engines (more commonly spoken of as compound, triple, and quadruple engines respectively), the use of high-duty valve gears, and many other improvements having for their common object the production of the largest possible amount of work from any given weight of steam passing through the cylinders. At works using large quantities of steam power, as in the case of water or sewage pumping stations, where the coal bill necessarily becomes a considerable item in the annual expenditure, it is therefore of primary importance that the engineer should be well acquainted with the best available means of frequently and fully investigating the behaviour of the steam in the cylinders of the various engines that may be under his charge. Any neglect to systematically perform such investigations may, even in a station of medium size, easily involve the waste of considerable sums annually in fuel for the want of a knowledge of the efficiency of the performance of each individual engine. The need for some convenient means of thus investigating the work of his engines was first realised by James Watt, who introduced the "steam-engine indicator," an instrument for the purpose of describing a diagram, the area of which has a definite relation to the amount of work done upon the piston by the steam in the cylinder. It will not be necessary to here describe the indicator in detail, but it may briefly be stated to consist of a small cylinder communicating with the engine cylinder, and fitted with a small piston, which the varying steam pressure drives upward against the resistance of a spring of a stiffness suited to the pressure. A lever, connected with the piston-rod of the indicator, imparts motion to a pencil, which traces the diagram on a card wrapped round a vertical drum, which is turned backwards and forwards by means of a string connected with the piston-rod of the engine. The figure thus drawn by the

indicator shows the varying pressure acting upon the piston of the engine at every point of the stroke; the mean pressure is thence readily ascertained, and the power of the engine calculated. The indicator diagram also affords invaluable information as to the interaction of the steam and cylinder walls, and enables defects in the design, setting, and working of the valves for the admission and exhaust of steam into and out of the cylinder to be detected and remedied, and the economy of the engine thus improved. By the teachings of the diagram of work performed the advantages of the expansive use of steam, compounding and condensing, can alone be fully appreciated.

A theoretical indicator-diagram of work upon the piston in a condensing engine, with early "cut-off" of steam, is shown in Fig. 1, and serves to illustrate the advantage of expanding steam in a single cylinder instead of using full pressure to the end of the stroke. It will be seen that full steam is used during a small portion only ($A\ F$) of the stroke of the piston, the remainder being completed by the pressure of the expanding steam; that the pressures gradually fall as the end of the stroke is approached, as roughly represented by the hyperbolic curve $D\ H$. The area of the diagram is a measure of the work done, and the portion $B\ C\ D\ E$ represents that performed by the "full steam" without condensation, $E\ D\ H\ J$ that done by expansion without condensation, and $A\ B\ J\ G$ that resulting from the use of the condenser. It is thus seen that by "condensing," by the use of high-pressure steam and expansive working, great economy is obtainable by the introduction of an earlier "cut-off," and a higher ratio of expansion, thus using at each stroke a less weight of live steam.

In all modern economical steam plants of any considerable size, the tendency is towards the use of high-pressure steam and high ratios of expansion in the cylinders. For this purpose a compound engine having two, three, or even four cylinders, becomes necessary. Theoretically, there is no difference in the expansive power of steam of given initial and terminal pressure, whether effected in one or two cylinders, provided the compound cylinders are correctly proportioned. The single-cylinder engine has considerable theoretical advantage over the compound engine, but, practically, the advantage lies decidedly with the compound principle. This arises from the circumstance that although very high rates of expansion are theoretically possible in the single-cylinder, the practical economical limits are soon reached, because high ratios of expansion involve high initial pressures and

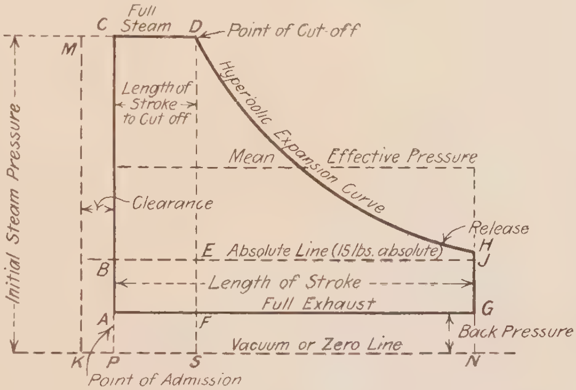


FIG. 1.—Theoretical Indicator Diagram—Condensing Engine.

great differences of temperature between live and exhaust steam. When the live steam enters a relatively cold cylinder a considerable initial condensation takes place, thereby largely neutralising the advantage of a high expansion ratio. This difficulty is met by permitting the steam to successively expand in either one, two, three, or even four cylinders, according to the initial pressure of the steam used, and the ratio of expansion adopted. We thus have what are known as the single, compound, triple, and quadruple forms of engines respectively, and it is in thus diminishing the effects of initial condensation with high expansion ratios that the main advantage of "compounding" lies. There is, however, a further advantage in that the multiple cylinder engine lends itself to the equal division of the work between two or

three cranks set at angles of 90° or 120° with each other, thus giving a more equable turning effect, and avoiding dead centres. In the distribution of the steam between two or three cylinders, each piston should give to its crank as near as possible an equal amount of work, and there should also be an approximately equal fall of temperature in the different cylinders.

From what has been said it will be gathered that a high initial pressure is necessary in order to get the full advantages to be derived from the use of steam in the compound and triple-cylinder engine. For compound engines a pressure of from 90 lbs. to 120 lbs. per square inch is required, and, where a steam pressure of 150 lbs. is available, triple expansion engines

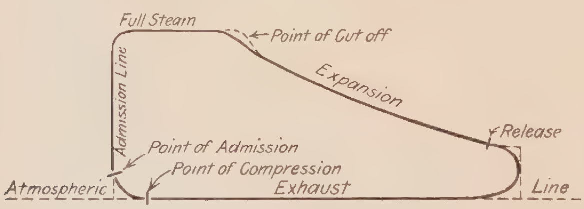


Fig. 2.—Actual Indicator Diagram—Non-condensing Engine.

will be more economical than compound. Higher pressures still are necessary for the quadruple expansion engine, but these are seldom used for municipal purposes.

The actual indicator diagram, as taken from the steam engine, differs considerably from the theoretical diagram given in Fig. 1, and may be considered under two heads, viz., those from non-condensing engines and those from condensing engines. From the study of the diagram from any given engine, much useful information may be obtained in addition to the power of the cylinders indicated by carefully observing the nature of the deviations from the theoretical diagram. The diagram shown in Fig. 2 is from a non-condensing engine, that is, one which exhausts directly into the atmosphere. It will be noticed that from the point of admission the steam pressure at once rises, and is well maintained to the point of cut-off, where a slight "wire-drawing" of the steam is indicated by the rounded corner of the diagram. The absence of any such wire-drawing in a diagram points to the efficiency of the valve gear. From the point of cut-off the steam works expansively through the remainder of the stroke till the "release" of the exhaust steam occurs at the point indicated. The exhaust line of the diagram falls to the atmospheric line through the exhausting of the steam being well carried out without back-pressure, and a small amount of "compression" takes place on the return of the piston before the admission of a fresh supply of live steam to the cylinder. A larger amount of compression than that shown would advantageously tend to decrease the amount of initial condensation in the cylinder, and to produce smoother working in the engine.

A practical indicator diagram from a condensing engine (that is one which exhausts into a vacuum) is given in Fig. 3, which fully explains the functions of the different parts of such a diagram. Following the diagram round from the point of admission of the steam (M) the following cycle of operations occurs at each stroke. Upon the admission of live steam the "clearance" space is first filled, and the pressure in the cylinder then rises to E, whereupon the piston moves forward under full steam to the point of cut-off. From this point the forward stroke is completed by the expansive force of the steam to the point of release. Upon the release opening to exhaust the pressure at once falls to J, and the piston returns because the vapour pressure in the condenser cannot be wholly removed, thus showing a certain amount of "back-pressure," as in the diagram. The exhaust ports being fully open on the return of the piston from J to K, a horizontal line is drawn till the point of compression is reached and the remaining steam is compressed to M, the point of admission. Here it meets the incoming live steam due to the advance opening or "lead" of the valves immediately before the commencement of a new stroke, and the steam pressure again rises to point E. In practice,

there are many variations in form from this diagram, and it is by observing these differences from time to time that defects in the working of an engine are detected. For example, if the "full-steam" line falls in the manner shown by the dotted line $E F G$, it indicates "wire-drawing" at the point of cut-off on account of narrow steam ports, insufficiency of valve opening, or throttling, and the steam is thus prevented from following up the piston at full pressure. The common slide valve, actuated by an ordinary eccentric, owing to the slowness with which it closes the port, always produces a certain amount of wire-drawing. To obtain a perfect cut-off the valve must open quickly, remain open till the point of cut-off, and then close quickly. There are several special valve devices designed to meet these conditions, of which the Corliss valve gears, which are very perfect in their action, are perhaps the best known, and have the merit of producing a very sharply defined diagram. A moderate amount of "compression" is shown in the diagram from K to M. This is brought about by closing the exhaust port a little before the piston has completed its stroke, thus compressing the steam still remaining in the cylinder into the clearance spaces. The extent of compression, or "cushioning," which may be advantageously employed depends mainly upon the speed of the engine. A large amount of cushioning is required in high-speed engines to arrest the momentum of the rapidly moving parts, but in engines with a slow piston speed a moderate compression will be sufficient to ensure smooth running. In engines having great piston speed and high ratio of expansion the exhaust steam may be compressed up to the initial pressure of the steam, in which case the cylinder becomes heated to the initial temperature, and the condensation of the fresh live steam upon entry is thereby greatly reduced. Cushioning is partly effected by giving the slide valve the requisite amount of "lead," that is, allowing it to open the steam port before the piston arrives at the end of the stroke. Want of lead on the valve, causing late admission of the steam, shows itself upon the diagram by a rounded corner such as C to D, or if very marked by a sloping admission line as from A to B owing to the piston having travelled through a part of the stroke before full pressure is upon it. In addition to the admission of steam before the end of the stroke, it will be observed from the diagram that its release on the other side of the piston also takes place before the end of the stroke.

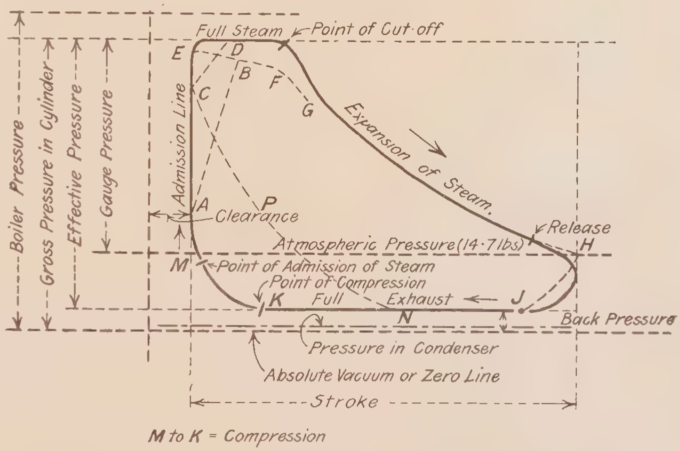


FIG. 3.—Actual Indicator Diagram—Condensing Engine.

This prevents excessive back pressure, and has the effect of rounding that end of the diagram as shown. If the steam were carried to the end of the stroke before opening to exhaust the diagram would approximate to the form shown by the line $H J$ indicating excessive and wasteful back pressure.

A leaky piston produces a diagram with a loop enclosing minus effective pressure—the pressures on each side of the piston tending to equalise, and initial condensation is shown by the sudden falling off of the pressure and corresponding fall of the expansion curve from the point of cut-off. This and re-evaporation may be detected by drawing the hyperbolic expansion curve. By the same means the

effect of a leaky slide valve upon the diagram would be revealed as it would raise the expansion curve at the expense of live steam. Excessive compression would produce an effect upon the diagram similar to that shown by the dotted line $N\ P\ E$ (Fig. 3). An indicator with too light a spring or too heavy a piston produces a shaky diagram having a wavy outline. Reference has been made above to the hyperbolic expansion curve, and it may be convenient here to observe that steam is not a perfect gas capable of expanding in strict accordance with Boyle's law, nor is the curve of its expansion strictly represented by a hyperbola. The expansion line, however, of a good diagram approximates to the hyperbolic curve so closely that it is used as a convenient datum for purposes of comparison. Its application in this connection frequently enables defects in the diagram, and consequently in the action of the steam valves, to be detected which might otherwise have escaped observation. On the left hand side of the diagram (Fig. 1) will be noted a space marked "clearance," and to which further reference must be made. The piston of an engine in practice does not, at the end of its stroke, come quite close up to the end of the cylinder. The small space thus left between piston and cover is necessary to allow for the wear of the journals and affords room for any condensed steam or priming which may occur. In addition to this there is also the volume of the steam ports between the valve faces and the cylinder. The spaces are collectively known as the clearance of the cylinder, and have an important bearing upon the expansion of the steam and the economy of the engine as they have to be filled with steam when "admission" occurs. Clearance, therefore, influences the thermodynamic efficiency of the engine mainly by altering the consumption of steam per stroke. Neglecting clearance, the ratio of expansion of steam in a cylinder, is equal to the volume of the cylinder divided by the volume to the point of cut-off, but if clearance be taken into account the true ratio of expansion is much less. Thus, referring back to Fig. 1, if $P\ N$ represents the volume swept through by the piston up to the point of release, $K\ P$ the volume of the clearance, and $P\ S$ the volume swept through during admission or to cut-off, then the apparent ratio of expansion is $P\ N/P\ S$, whereas the real expansion is $(K\ P+P\ N)/(K\ P+P\ S)$. The losses arising from clearance cannot in practice be avoided altogether, but may be considerably reduced by the "compression" of a portion of the steam on the return stroke as already explained. W. H. M.

Infectious Diseases.—(*See* "ZYMOTIC DISEASES.")

Intake.—In water supply the "intake" is the source or point on the banks of a river or lake at which the supply is derived, and from which it is conveyed to the waterworks pumping station for subsidence and filtration. The site for the "intake works" should be chosen with great care. At the point selected there should be no tendency for the river to deposit silt or *débris* of any kind, and for this reason a convex bank or straight reach, with suitable training works where necessary, is preferable. The intake chamber should be situate below the dry-weather level of the river, so as to exclude floating matter, but above the bed of the river to prevent silt and deposit gaining access. The inlet should always be protected by means of a grating to prevent any large objects entering. The intermediate position, or level, of the intake as above enables water to be drawn off in cold climates between the floating ice and the ground or anchor ice. Suitable means for flushing out the intake chamber should also be provided. There are two intakes to the East London Waterworks on the river Lea—one at Ponder's End and the other just below the Ordnance Factory at Enfield. Another intake connected with these works is situate on the Thames just above the Sunbury Weir at Wheatley's Ait. It is of paramount importance that all water intakes from rivers should be as high up the stream as practicable,

above sewer-outfalls or other discharges contributing to the pollution of the water.

Intercepting Sewer.—(*See* "SEWERAGE.")

Interceptor.—A bent pipe so formed that while liquids are permitted to flow through it, air is prohibited. (*See* "DISCONNECTING TRAPS.")

International Process of Sewage Purification.—This system of sewage purification employs a magnetic precipitant and deodorizer called "ferozone," and the liquid is afterwards filtered through a "polarite" filter. The sewage of Mangotsfield is treated by the International Company's process with Candy upward flow precipitation tanks, and the effluent has been very favourably reported upon. (*See* "POLARITE" and "FEROZONE.")

Inverted Siphons.—(*See* "SIPHONS.")

Irrigation, Broad.—(*See* "SEWAGE DISPOSAL.")

Isolation Hospitals.—**Acts of Parliament—Provision of Isolation Hospitals—Local Government Board Requirements as to Wards—Porter's Lodge and Receiving Blocks — Administrative Buildings — Ward Pavilions — Laundry— Mortuary — Protection Against Fire — Telephonic Installation—Cost of Hospitals.**—Local authorities first obtained powers to build or otherwise arrange for hospitals to deal with infectious disease by the passing of the Sanitary Act of 1866. These powers were increased by the Public Health Act, 1875, and the Isolation Hospitals Act, 1893. In 1883 the Epidemic and other Diseases Prevention Act was brought into force as an amendment to the Public Health Act (England), 1875. It provides for the prevention of any threatened pestilence, such as epidemic, endemic, or infectious disease, and makes regulations for the speedy interment or other disposal of the dead; house - to - house visitation; provision of medical and hospital accommodation; and also provides for the cleansing, ventilation, disinfection, and the guarding against the spread of disease. The Infectious Disease (Prevention) Act, 1890, in addition to other matters, enables local authorities to make free provision from time to time for temporary shelters, or house accommodation, with the necessary attendants, for the members of any family in which an infectious disease has appeared, who have been compelled to leave their dwelling for the purpose of enabling such building to be disinfected by the local authority. The Isolation Hospitals Act, 1893, was promoted to enable county councils to establish hospitals for the reception of patients suffering from infectious disease. This Act does not extend to the administrative county of London, or to any county borough, or, without the consent of the council for the borough, to any borough containing, according to the census for the time being in force, a population of 10,000 persons or upwards, or to any borough containing a less population, without the like consent, unless the Local Government Board by order direct that the Act shall apply to such borough. Under this Act the council of every county may, on such application being made to them and proof adduced, provide or cause to be provided a hospital for the reception of patients suffering from infectious diseases. An application to a county council for the establishment of an isolation hospital may be made by any one or more of the authorities having jurisdiction in the county, or any part of the county. Such an application may be made in pursuance of a resolution passed at a meeting of any authority by a majority of the members assembled thereat, and voting in a manner in which votes are required by law to be given at a meeting of the authority. An application for the establishment of an isolation hospital may also be made by any number of ratepayers not less than 25. Such application shall be made by petition, and shall state the district for which the isolation hospital is required, and the reasons which the petitioners adduce for its establishment. In 1899 an Act was passed to

extend the Infectious Disease (Notification) Act to districts in which it has not hitherto been adopted. It extends to and takes effect in every urban, rural, and port sanitary district. This Act provides that the head of the family, or the nearest relative of the patient resident in the building, must give immediate notice (in case of infectious disease) to the Medical Officer of Health; that the medical practitioner attending the patient, on finding a case of infectious disease, must notify to the Medical Officer of Health for the district the name of the patient, the situation of the house, and the infectious disease from which the patient is suffering. The Isolation Hospitals Act, 1901, which is an amendment of the Isolation Hospitals Act, 1893, provides that any local authority (including a joint board) within the meaning of the Public Health Act, 1875, which has provided under this Act, or any local Act, a hospital for the reception of the sick, may, with the sanction of the Local Government Board, and with the consent of the council, transfer it to the council of the county within which the hospital or any part of the district of the authority is situate. Any hospital transferred under this section shall be appropriated to a district formed under the Isolation Hospitals Act, 1893, and may be adopted as an isolation hospital; and any hospital so appropriated shall be treated as if it had been originally established under the Act for the district. Any expenses incurred by a county council in or incidental to the transfer of any hospital under this Act shall be defrayed as structural expenses incurred by a hospital committee within the meaning of section 17 of the principal Act.

Provision of Isolation Hospitals.—Hospital accommodation for infectious and contagious diseases is required more particularly in towns than in rural districts; still some provision should be made for the most isolated villages. The best arrangement for small populations is by the provision of a hospital accessible from several villages. Such a building could be planned with accommodation for four or more cases of infectious disease, and be well isolated. In towns wards should be placed in one or more pavilions, with space enough for the erection of other blocks, temporary or permanent. In all hospitals there must be a division between the hospitals coming within the category of so-called fever hospitals. They may be divided into two classes: those of the sanatoria type, pure and simple, and those of the hospital type. In all cases it is necessary that small-pox cases should be separated from scarlet-fever and diphtheria patients. In the case of infectious hospitals the ratio is about twenty beds for a population of 25,000. In twenty-seven important towns, having a population of nearly 4,500,000, there are twenty infectious beds to each 29,000 persons. At the present time London has about 10,216 beds in the hospitals of the Metropolitan Asylums Board. Some authorities advocate accommodation for infectious cases in the proportion of ten beds per 10,000 of population, with arrangements to admit of three different infections in both sexes. It is well to provide an average number of two or three simultaneous infections, and this should be supplanted by temporary arrangements in case of necessity. When authorities contemplate the erection of a hospital for small-pox it may be laid down, with a view to lessening the risk of infection, that the erection of the hospital should not be on a site where it would have within a quarter of a mile of it as a centre either a hospital, whether for infectious disease or not, or a workhouse, or any similar establishment, or a population of 150 to 200 persons; or upon any site where it would have within half a mile of it as a centre a population of 500 to 600 persons, whether in one or more institutions or in dwelling-houses. It should be understood that even when the above conditions are strictly fulfilled, there may be circumstances under which the erection of a small-pox hospital should not be contemplated. Cases in which there is any considerable collection of inhabitants just beyond the half-mile zone should always call for special consideration. The site of a hospital should, if

possible, be in the open country, and so maintain a maximum amount of purity of air being breathed by the patients. Presuming that the situation is unfettered, except by hygienic requirements, the qualities of a site more favourable to an isolation hospital is a clean, porous, and dry soil, with free circulation of air round it.

Local Government Board's Requirements as to Wards.—The Local Government Board, in their memorandum of requirements and suggestions relating to the provision for infectious disease cases, state that "any building intended to contain infected persons or things should be placed at least at a distance of 40 ft. from the boundary of the site." The following minimum amount of space per patient should be provided in wards for infectious cases:—

Wall space, per bed.	12 ft.
Floor space	144 sq. ft.
Cubic space	2,000 cu. ft.

In designing isolation hospitals it will be found that if the above amount of floor area is to be adhered to, then the requisite cubic space can only be obtained by adopting a height of some 14 ft. As this height is somewhat excessive in other than wards of great length, it is desirable that a height of, say, 12 ft. or 13 ft. should be adopted, and the floor space be correspondingly increased. The following table gives the requisite space, and at the same time provides a ward more suited for supervision:—

Wall space, per bed.	12 ft.
Height of ward	13 ft.
Floor space	156 sq. ft.
Cubic do.	2,028 cu. ft.

Porter's Lodge and Receiving Blocks.—The entrance to a fever hospital should be so situated as to allow for the separate admission and discharge of patients, and also for the delivery of stores and for tradesmen to transact their business without coming in contact with the infected parts of the hospital. In the case of small isolation hospitals one entrance should suffice for all purposes. In the case of large hospitals, however, it is desirable that the porter's lodge should be so situated as to allow of the provision of two entrances, one for infected to enter, and with a carriage drive direct to the hospital buildings, and another for non-infected, with a roadway leading to the administrative buildings. The porter's lodge usually comprises an office and waiting-room, sitting-room, kitchen, and the usual out-offices on the ground floor, with at least two bedrooms and a bath-room on the first floor. In some cases the rooms for receiving and discharging patients are provided in connection with this building. When this provision is provided in a distinct block, the receiving apartment should comprise a room for the medical officer to examine the patient, patients' clothes store, and bath-room. The discharge block should comprise an undressing room, where the patient is relieved of the hospital clothing and then bathed. Adjoining the undressing-room, and dividing the discharge room, should be placed a bath-room, in order that the patient, after bathing, may receive his own clothes and pass into the discharge-room, which should also act as a waiting-room for relatives or friends of the patient. In some hospitals two receiving and discharge blocks are provided, one for scarlet fever, the other for diphtheria and enteric fever.

Administrative Buildings.—The administrative buildings should provide accommodation for medical and nursing staff, stores, cooking, &c. In small isolation hospitals provision is made for matron's quarters, nurses' sitting- and mess-room, medical officer's room, dispensary, mending-room, stores, and the necessary sleeping accommodation for the staff. In large hospitals the medical superintendent is provided with a residence separated from the other buildings. The kitchen and stores should be placed centrally to allow of easy distribution of food and stores. The matron's department, which comprises linen stores, needle-room, and the like apartments, should also be placed in the central administrative block. In the case of

small isolation hospitals the nurses' departments will also be provided in the administrative building. When, however, there is a large staff of nurses, as in the case of large hospitals, they are housed in a separate and distinct building. When a nurses' home is provided it should contain mess-rooms, general sitting-room or common room, reading-room, and bedrooms. The bedrooms should measure 13 ft. by 8 ft. 6 in., or 12 ft. by 9 ft. The whole of the rooms should be heated by radiators; fireplaces should not be provided in the bedrooms, as they are rarely used. Provision should be made for at least one sick-room for use as occasion may require. Water-closets, lavatories, slop-sinks, and baths should be provided on each floor in proportion to the number of beds. Suitable provision should be made in large hospitals for medical students undertaking a course of studies. In this case a well-lighted and ventilated lecture-room should be provided in connection with the administrative buildings. When provision is made for housing students, they should be accommodated in a block quite distinct from the other buildings.

Ward Pavilions. — In considering the number of beds apportioned to each disease, it should be borne in mind that scarlet fever demands almost a half of the total bed accommodation. As scarlet fever is, in the large majority of cases, an acute disease during the first one or two weeks only, and seeing that it is generally admitted to be most desirable to separate these cases from convalescents, the best arrangement is to have two separate blocks—a small one for acute cases and a large one for convalescents. The small pavilion should have a couple of one- or two-bed wards for the isolation of delirious and noisy cases. The separation wards should be provided with separate and distinct water-closet and slop-sink. The walls and ceilings of all wards should be finished with a plaster or cement face, and be painted or varnished. The angles made by the walls with each other and with the ceiling should be finished with quadrant shaving the concave surface to the ward. The whole of the ceilings should be quite plain, free from all projections, angles, or cornices which accumulate dust. The floors of all wards should be constructed of such material as will be capable of being easily cleaned. Wood as a material for floors in wards is far from satisfactory, being full of joints, which frequently open and become receptacles for impurities. The best material for floors is terrazzo, or one of the many jointless floors now in general use. The latter are preferable, being much warmer. The windows, where the cost will allow of it, should be double-glazed to prevent the loss of heat and to maintain an even temperature in the ward. They should have an area of not less than 1 ft. of glass for every 70 cu. ft. of ward space. A window should be arranged between each pair of beds, and it is advisable to place a window in each corner of the ward, between the end wall and the last bed. The windows should be divided into two parts, of which the upper part is made to fall in and form a hopper ventilator, glazed hoppers being fixed on each side; the lower portion being formed as double-hung sashes. The doors in the wards should be so arranged as to facilitate nursing, and be large enough to allow the passage through of the sick on movable stretchers. The doors should afford an opening of from 3 ft. 8 in. to 4 ft. The construction of all doors in wards should be such as to present as few projections or places for the accumulation of dust as possible. The upper part of entrance doors to wards should be glazed. The ward adjuncts for water-closets, slop and scalding sinks should be separated from the wards by intervening lobbies, having windows at each side. It is advisable to fix in each of these lobbies a radiator capable of raising the temperature to a higher degree than that of the ward, so that the air is drawn from the ward into the lobby instead of *vice versâ*. In the disconnecting lobby between the wards and water-closet and slop-sink two openings should be formed in the external walls, one for the reception of soiled linen (which can be drawn through by

the attendant on to a trolley outside), and a smaller opening in which stools can be kept for inspection. It is necessary to fix a tightly-fitting internal iron door to each of these openings. A nurses' duty room should be provided in connection with each large ward; it should lead direct from the corridor and be so situated as to overlook both the principal and the separation wards. It should contain a gas cooking-stove, dresser, washing and rinsing sink, and a small cupboard. Provision should also be made in each pavilion of a water-closet, lavatory, and a robing-room for the use of the staff. It is advisable to provide open fireplaces in all wards in addition to the heating by hot-water pipes and radiators. In the case of large wards down draught stoves should be provided, fixed in the centre of the wards. Suitable provision should also be made for the admission of fresh air and the extraction of vitiated air. (*See* "VENTILATION.")

THE LAUNDRY.—The laundry, which is one of the most important departments of an isolation hospital, should be so situated as to allow of the receiving and dispatch of linen without any undue distance being traversed. This building should, however, be well removed from the ward pavilions and the administrative buildings. The laundry should contain two departments, one for the staff and the other for the patients' washing. Adjoining the patients' washhouse provision should be made of a foul-washhouse for receiving and steeping articles soiled by excreta. It should be fitted with tanks classified for scarlet fever, enteric fever, diphtheria and isolated cases. The laundry proper should comprise a washhouse, drying apartment, ironing rooms and receiving and delivery rooms.

Provision is necessary for disinfecting all clothing of the patients, bedding, &c., from the wards. The disinfecting chamber should adjoin the laundry and be fitted with a steam disinfector. The disinfecting apartment comprises two chambers, one for receiving the infected clothing and the other for receiving the clothes after they have passed through the disinfector. There should be no communication between the two chambers. (*See* "LAUNDRIES.")

It is also necessary to make provision for the destruction of all refuse, which frequently consists of mattresses and bedding on which patients have been lying, bandages, portions of food, ordinary sweepings, and solid and liquid excrement. This building is best placed so as to adjoin the laundry.

MORTUARY.—Every hospital should be provided with a mortuary, which should have facilities for isolating bodies for the purpose of viewing and identification. The mortuary should comprise a room fitted with slabs for the reception of dead bodies, visitors' waiting-room, and viewing closet. A *post-mortem* room should adjoin the mortuary and have a north light. This room should be well lighted and ventilated and furnished with sinks, lavatory, anatomical table, and glass shelves for the storage of bottles. The whole of the walls should be faced with glazed bricks or glazed tiles, and the floor covered with terrazzo paving.

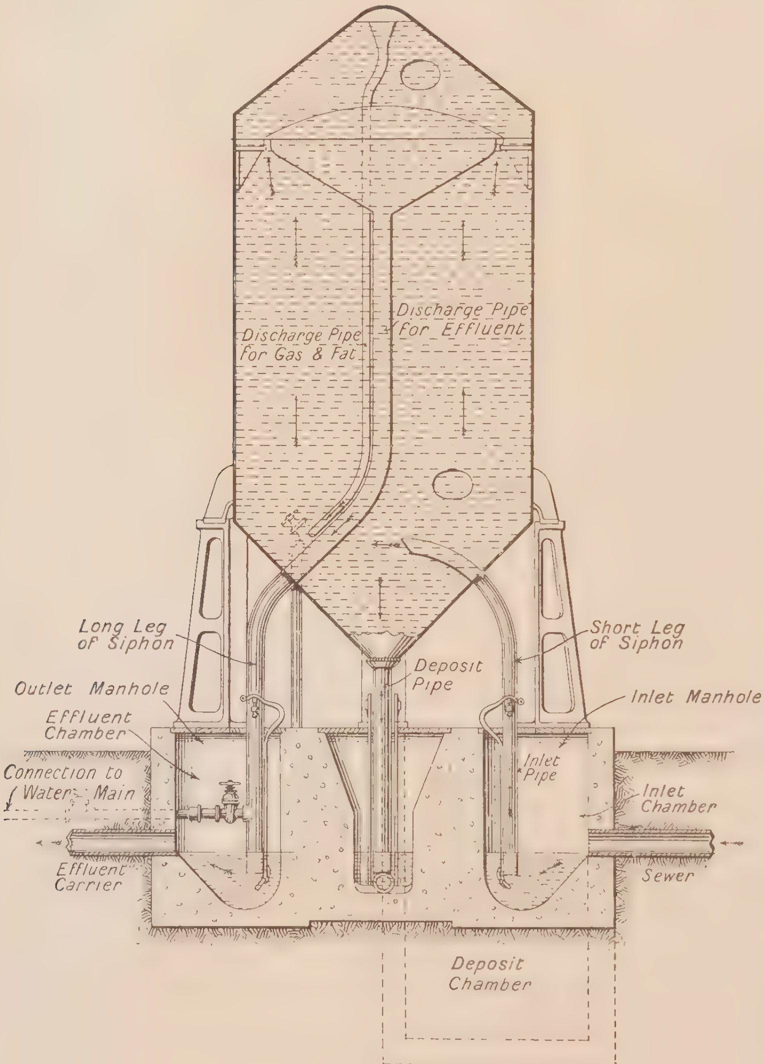
PROTECTION AGAINST FIRE.—Where buildings are of two or more storeys in height they should be provided with external fire-escape staircases for use in cases of emergency. Suitable provision of fire appliances is also necessary to protect the buildings against fire, and the most ready means should always be at hand with which to attack a fire at its outbreak. Fire hydrants fitted with hose and hand pipes should be fixed in every building, and, in addition, fire buckets should be provided as an extra precaution.

TELEPHONIC INSTALLATION.—A system of electric intercommunication should be provided between every part of an institution, either by means of telephones or bells. Telephonic communication between each of the ward pavilions and the administrative buildings is also necessary for cases of emergency. A bell-call should also be provided from the medical superintendent's and the matron's office to the porter's lodge and the nurses' home; also from the stores, laundry

and porter's lodge; a signal code in reference to the supply of steam, outbreak of fire, or other call, being previously arranged.

Cost of Hospitals.—The cost of erecting hospitals for infectious disease has been found to vary considerably. The average cost of the Metropolitan Asylums Board's Hospitals, which provide accommodation for some 500 beds in each institution, is about £450 per bed. The cost of isolation hospitals in the provinces is found to be from £500 down to £272 per bed; as an example Baguley, Cheshire, cost £512 per bed; Burnley £486; Coventry £308½; Liverpool £456½, while the Bridlington isolation hospital cost only £272 per bed.

A. C. F.



Kessel Separator.

"Ives" Tank.—The "Ives" upward-flow self-acting continuous precipitating tank of the Universal Sewage Purification Co. was introduced by Mr. Ives in 1894 and 1895, and has been installed by several authorities. It is somewhat complicated in design, is circular in plan, and includes arrangements for aëration. As a preliminary preparation, the centrifugal reduction of the coarser solids by whirling them against bafflers is employed, by which they are broken up and brought into suspension for subsequent chemical treatment. The precipitant used in connection with this tank is Spence's alumino-ferric in the form of slabs of suitable size, and the tank effluent is passed over land, or through coke or ash filter beds.

Kessel Separator.—This is a boiler-shaped apparatus first introduced in Germany with the object of the economical removal of suspended matters from sewage. It consists of an elongated vertical cylinder having an inverted cone-shaped bottom and a domed top as illustrated in the figure. The vessel is erected on iron or brick supports over the line of sewer, and the flow of sewage is siphoned through the cylinder at such a rate as will permit of the deposition of solids, the liquid portion being discharged

with a loss of head of about 3 in. only in the level of the sewer. From the figure it will be seen that the inlet or short-leg of the siphon takes its sewage from a small manhole and discharges within the vessel at a point vertically over a central deposit pipe into which the coarser solids are deflected. As indicated by the arrows, the sewage liquid rises and enters a narrow annular slot around an internal inverted-cone, the lower portion of which connects with a discharge or effluent pipe (forming the long-leg of the siphon) which, passing downwards through the lower part of the Kessel, terminates by means of a trapped end in a second manhole. The end of the long-leg is made about 3 in. lower than the level of the inlet or short-leg so as to ensure the necessary siphonic action upon which the motion of the sewage through the Kessel depends. Needless to say the whole apparatus must be made and kept perfectly air-tight throughout, and accumulations of air from the sewage or elsewhere in the top of the vessel would interfere with its proper action. A further pipe is also provided from the apex of the cone, as shown in the illustration, for the discharge of gas and fat. To start siphonic action through the Kessel it is necessary, as in the case of any other siphon, to first fill the apparatus with water and then simultaneously open the valves on the legs.

The size of Kessel for any given case depends greatly upon the nature of the sewage, but the capacity must be large enough to give a sufficiently slow speed of flow to permit of the deposition of the solids. A cylinder 8 ft. in diameter will deal with from 2,000 to 4,000 gallons per hour, and one of 30 ft. diameter from 25,000 to 50,000 gallons per hour. For physical reasons the height of the vessel must not exceed the limit of the atmospheric pressure as compared with the specific gravity of the sewage, or say, from 27 to 30 ft. It is stated that with ordinary domestic sewage about 70 % of the solids in suspension are removed.

The Kessel is not at present in use in this country, but there are a number of such plants at work in Germany and others in course of erection. The design of a Kessel to meet any particular case naturally depends upon the class of sewage to be dealt with and the rate at which its suspended solids are found to precipitate, but, broadly speaking, it is claimed equally thorough precipitation of solids can be secured in either the Kessel or in the "Commin-Separator" (*see* "COMMIN-SEPARATOR") at half the cost of septic or ordinary sedimentation tanks.

Lateral Water Filtration.—A combination of the lateral and downward flow of water through filter beds has been adopted in order to secure rapidity of action and economy of construction and maintenance. This principle is embodied in the McGregor system, which has been introduced in Canada. Round a sunken circular pure water reservoir a number of concentric filter beds are built, each ring from the centre outwards being stepped on a higher level, the base of the outer ring being on a level with the top of the inner bed. The number of the concentric rings, their width and depth, and the composition of the bed may be varied according to the amount of water required, the quality of the water and the degree of purity to be arrived at. The bases of the beds have a slight inward slope, and at the base of the inner walls are openings—protected with metal screens fitting in iron gratings. The inner bed has, in addition to these screens, duplex wire strainers, through which the filtered water flows into the reservoir. The beds are divided into sections by means of partition walls, so that one or more sections can be put out of action for cleansing or repairs without interrupting filtration. The crude water is sprinkled over the top, and outer, bed, and flows downwards and sideways, from bed to bed. The stresses on such beds are very slight and evenly distributed. Armoured concrete may be used for their construction, and the reservoirs and beds may be protected from the action of sun and frost by a roof.

Laundries.—These establishments fall into two main divisions: (1) those equipped for hand labour; (2) those wherein machinery is driven by mechanical power. Each of these divisions is, for purposes of consideration, divided into four classes :—

(*a*) Private laundries.
(*b*) Trading laundries.
(*c*) Baths and wash-houses laundries.
(*d*) Public institutions laundries.

(1) Hand Laundries are found chiefly in connection with private houses and certain descriptions of public institutions, such as schools, workhouses, lunatic asylums. For some years the tendency has been for the genuine trading hand laundry to disappear, and the new Factory and Workshop Act, 1907—amending the Factory and Workshop Act, 1901 (referred to as "the Principal Act")—has hastened this desirable consummation. The sanitary requirements in hand laundries necessitate the provision of good ventilation, lighting, drainage, and an adequate supply of fairly soft water. (*See* "Water Softening.") There should be at least two rooms; the wash-house and the ironing and packing room. A drying closet may be built into one corner of the ironing room, or the iron heating stove may be screened off so as to form a drying closet; but in such an establishment a built-in brick closet is best. This should be in two divisions each of them having a door. Between the divisions there should be a kind of cell to contain an iron heating stove, and there should be direct communication between this heating chamber and the closet by means of hot air flues, provided with dampers. The heat can then be directed into or shut off from one or both of the divisions as desired. In this way it is possible to economise heat, and, at the same time, afford workers the necessary protection from radiation. When one section of the closet is being loaded, or unloaded, heat is shut off and the door opened. In large establishments it may be necessary to provide more heat than that produced by the above method. This can be obtained by placing a small furnace beneath the closet, or by providing hot air or steam radiators. The floors should be impermeable, and for the wash-house, concrete, floated with good cement, is best, as it is easy with this material to arrange for a slight inclination towards a gutter, placed centrally or against the lateral walls, and communicating with a trapped drain. The plant usually consists of steeping tanks and washing troughs. These should be either of hard wood or salt-glazed stoneware. Rotary washing-machines and hydro-extractors are now made for driving by hand-power (see below).

(2) Power Laundries are equipped with machines which are generally worked by steam-engines, although gas-engines and hydraulic and electric motors are also used.

(*a*) Private Laundries should contain not less than two rooms, (1) wash-house, fitted with washing troughs, steam-driven washing-machines, wringer or hydro-extractors; (2) ironing and packing room. This last may be fitted with strong tables for hand ironing, or with ironing machines. A good plan is to place the drying closet between the two rooms, with a door opening into each, so that the wet linen may be inserted from the wash-house side, and when dry may be removed by the other door. The floor of the wash-house must be smooth and impermeable. In small laundries, induced draught will be sufficient for ventilation; there should be inlet grids with air-filtering boxes near the ground, and outlet grids, preferably communicating with vaned cowls in the roof. The latter should be near the chimney stack, as the heat thus gained will become the accelerator of circulation of air.

(*b*) Trading Laundries.—An essential point in all large laundries is that the establishment should be planned so that the soiled linen enters at one door, and after being counted and sorted, passes on to be steeped, washed, rinsed, dried, starched, ironed, and packed, and so out at another door. We must, therefore, have not less than four main rooms, preferably on the ground floor, with engine and boiler-house attached, and ample sanitary

accommodation near, but having no direct communication with any of the working rooms. The first room is the receiving department, where the linen is counted and sorted, table, bed, body, and kitchen articles forming different heaps to be treated separately. This room being the most exposed to contamination should be fitted as plainly as possible to facilitate cleansing. The wash-house should come next, and communicate either by means of a corridor, or a trap-door in the partition wall, with the receiving department. The wash-house must be well lighted, either by means of sky-lights or windows placed rather high up. The walls must be smooth, white-washed at the upper part, but having a dado 6 ft. high, painted in oil colour. The floor should be of concrete with a coating of cement, and given a slight inclination towards a draining gutter, placed either down the middle of the room or against the walls, such gutters being protected by iron grids, and connected with trapped drains. In order to economise power, the heavy rotary washing machines and hydro-extractors should be placed as near the ironing room partition as possible, as this will simplify the planning of the shafting for transmission of power, reduce its extent, and lessen the length of belting. It is a good plan to run both washing and ironing machines from one main shafting, as this not only economises material and power, but the pulling from right to left tends to equalise the strain and so conduces to smooth running. Against the opposite wall there should be large steeping tanks of either galvanized iron or salt-glazed stoneware, and washing troughs of hard wood or stoneware.

Tanks and troughs should be fitted with cold and hot water (or steam) service pipes and taps, and large waste valves. The wastes of tanks and troughs, and also of all machines, should discharge through a free opening over the drain, not directly into it; by this means the dangers of siphonage (of water or gases) are prevented, and stoppages arising from articles being dropped through are avoided. On reaching the wash-house, all very soiled linen (body, bed, and kitchen chiefly) is steeped in the tanks. If the fouling is of an organic nature (blood or excreta), cold or lukewarm water, with a very little soda should be used to soften, but prevent coagulation. After steeping, the articles are generally treated by hand in the washing troughs to remove stains, and are then passed on to the washing machines. There are a large variety of washing machines, but those most commonly used are of the rotary type, and consist of an outer stationary cylinder and an inner revolving cage. Both cylinder and cage are provided with doors, and may be made of wood or metal, or the cylinder may be of metal, and the cage of wood, or *vice versâ*. The outer casing should be fairly solid, and fitted with hot and cold water taps, steam valve, water gauge, large outlet or waste valve, and fast and loose pulleys for the transmission of power, with starting and stopping gear. The cage is made either of rods placed close together, or of perforated sections, so as to admit water freely. The rods or the sections may be so arranged as to present an internal corrugated surface, or "rubbers" may be provided. In many cases, a series of metal tubes or a rounded slat of hard wood, are placed like a mid-feather to act as lifters. When the linen is packed in these cages, the doors are closed, hot water is admitted and dissolved soap and soda added through a hopper. The water may be brought to the boil by admitting steam. The machine is then set in motion by bringing the driving belt from the fast to the loose pulley. Then the cage revolves, rolling over the linen, carrying it half up the revolving circle, and allowing it to fall back into the soap suds; meanwhile a rain of soapy water falls through the perforations. In many machines, this action is increased by providing horizontal bands of metal or wood on the outer periphery of the cylinder, which act like cups, lifting the water which descends through the perforations. Were the cage to revolve only in one direction, the linen would not be properly

cleansed, as it would soon be formed into a tight ball, so the revolution of the cage is automatically reversed at every five or six revolutions. The cleansing action of such machines consists of a series of motions, combining rubbing, rolling, and squeezing, meanwhile forcing the water through the fabric. Without stopping the machine, the soapy water can be emptied by opening the waste valve; then hot water can be admitted for the first rinse, followed by rinses in warm, and finally in cold water. After this, blueing fluid may be introduced. Handling is thus reduced to a minimum, and all operations made as automatic as possible. After washing and rinsing, the linen may be passed through wringers or placed in hydro-extractors. The hydro-extractor consists of a strong outer casing and an inner perforated basket, which is made to revolve in an upright position. The wet linen is packed in the basket, which is then set in motion and driven at a high speed (from 800 to 1,500 revolutions per minute), the centrifugal force expelling the water, which, escaping through the perforations, is drained off. From the wringers or hydro-extractors the linen may be either starched (by hand or machinery), or may pass direct to the drying closets. These may consist of rooms heated by means of waste gases from stoves, or by steam passing through radiator coils, or the room may be fitted with a series of draw-out horses on which the linen is hung. If an ordinary drying room is used, it should be in duplicate, as the closet has to be cooled down before the attendant enters to hang up or remove the linen. From the drying closets the articles pass on to the ironing room. Here small articles and finery are ironed by hand, but most of the linen handled is dealt with on elaborate machinery. Bed and table linen is generally treated on large machines of the "Decoudun" or multiple roller types. The "Decoudun" machine consists of a concave steam chest, forming on the top a polished metal bed, on which a large hollow roller, covered with flannel, and sheeting rests. Steam is admitted into the bed at a high pressure, and consequently a pressure-gauge and safety-valve are necessary. The linen is placed on the lip of the bed and the revolving roller guides it gently through, drying and polishing it as it goes. Two or more passages are necessary. In the multiple roller machines, the steam heated bed has two, three, or more depressions, in which flannel covered rollers revolve. In such machines the heating surface is larger and the action more rapid. A large variety of more or less complicated machines are now made for ironing shirts and collars and cuffs, for goffering, and so on. From the ironing room the linen passes to the despatch department, where it is inspected, checked, and packed. It will be seen that a well ordered laundry offers considerable safeguards to health, as the linen is handled as little as possible, the soiled being kept away from the clean; it is, moreover, subjected to the action of soap and steam. The ventilation of such an establishment must be efficient, and this can rarely be attained by any "natural" system of inlets and outlets, even if the outlets be heated. Mechanical propulsion or extraction is necessary. This is usually accomplished by means of fans placed high up in the walls or the roof, in an opening communicating with the interior and exterior of the building. These fans may be placed so that they extract vitiated air and steam from all departments. In large establishments where the extraction is considerable, it may be necessary to regulate the introduction of fresh air, which is usually drawn into a cleansing and warming chamber by means of a suction fan, and then blown through air conduits, provided with regulator inlet grids in each room.

(*c*) Laundries attached to public baths and wash-houses (q.v.) are now often elaborately fitted up.

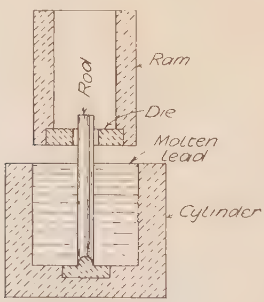
(*d*) PUBLIC INSTITUTION LAUNDRIES should be planned on the same principle as trading establishments, to secure a regular circuit, the clean linen being kept apart from the soiled, once it has left the wash-house.

Whenever possible all departments should be on the ground floor, whether in a separate building with top-lights, or, as is often done, in the basement. Only in the latter case special attention must be paid to ventilation, and artificial lighting becomes necessary. Unless the laundry is at some distance from the institution, the corridors near dormitories may be connected with the receiving room by means of shutes, so that the soiled linen can be removed to the laundry rapidly without difficulty. Such shutes must be smooth and impermeable to permit of periodical flushings, and provided at the corridor end with tight-fitting doors. Linen from infectious diseases wards is placed in galvanized iron bins containing some disinfecting fluid, and is then removed to the wash-house. After steeping for a prescribed number of hours, the linen is removed and washed separately. After the first soap wash (or breakdown), the second soap suds are boiled during the process of washing by means of the admission of steam under pressure. The liquid from the disinfecting bins and the washing machines used for infected linen, or linen soiled with blood and excreta, should be run into a special steam-tight tank, built beneath the floor, and boiled for some minutes by the admission of steam, then allowed to cool before being discharged into the sewer. The washing machines for this class of laundry are usually of a heavy type with strong doors, as much steam is used, both to facilitate cleaning and as a bactericide. Foul rotary-washing machines are made to deal with soiled body and bed linen. This machine consists of a single cylinder, of heavy metal, hung horizontally in bearings supported by standards. A casing of splash-boards is provided, partly enclosing the lower section of the cylinder. The cylinder has a steam-tight door, and also a large orifice protected by a grid and a screw-down cap. The foul linen having been placed in the machine, the door is fastened close and the cap unscrewed; then cold water is admitted and the machine set in motion. Plenty of water must be used to soften and remove dirt, which is carried away by the rush of water as the cylinder revolves. After a few minutes hot and cold water is run together, then the machine is stopped, the cap screwed down, and soap and water admitted, the regular processes of washing, boiling, and rinsing being pursued. Such machines, like the ordinary rotaries used for treating infected linen, should have two-way waste cocks, so that the water may be discharged either into the disinfecting tank or direct into the sewer. In institution laundries the wash-house and drying closets are relatively of more importance than the ironing room, thus differing from a trading establishment. In school, workhouse, and asylum laundries, where inmates often take a share in the work, special precautions must be observed in fencing machines and providing safety guards, protecting all working parts.

Lavatory Basins.—Now almost exclusively made of white glazed earthenware. There are three types: (*a*) Tip-up lavatories; (*b*) plug basins; and (*c*) "Rivulet" basins. In the first-named the basins are emptied by tipping their contents into containers below them, to which the waste pipes are fixed. Although convenient in hotels and other public places where the basins are in constant demand and rapid emptying therefore desirable, they can hardly be regarded as sanitary in view of the large soiling surfaces exposed. Plug basins, which are the most frequently used, are made as self-contained fittings, or may be fixed under marble, slate, or other slabs. In selecting them particular attention should be paid to the waste pipes and overflows. In hidden standing overflows in which the water contained by the basin is in contact with that in the overflow, and in basins in which water enters through the waste pipes, there is great risk of carrying infection from one user to the next. The spread of skin disease, there is reason to think, is greatly due to these types of appliances, which are frequently to be found in public places. Rivulet basins are useful

in hospitals, schools, &c. They are basins in which a depression is substituted for the bowl, water flowing constantly through it. Although very sanitary, the hands being washed in running water, they tend to waste water, and can only be made use of in special circumstances. All basins should be fixed free of all enclosure.

Lead.—The chief ore of lead is galena, or sulphide of lead, which has a crystalline form and striking lead-like lustre. It is smelted and run into half-round troughs to form pigs weighing 1 cwt. each. Sheet lead is generally made by casting a thick block weighing from 4 to 6 tons and passing it under metal rollers



Press for making Lead Pipes.

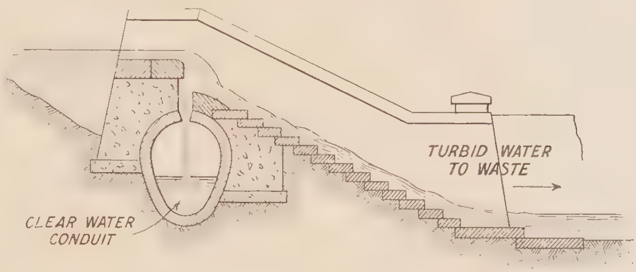
until it is reduced to the thickness required, when it is called milled lead. The sheets are from 24 ft. to 36 ft. long, and 5 ft. to 8 ft. wide, the finished thickness varying from $\frac{1}{20}$ in. to $\frac{3}{16}$ in. thick, but they are generally known by the weight in pounds per foot super., say, 3 lbs. to 10 lbs. In roof work the lead for aprons, flashings, and soakers is 4 lbs. or 5 lbs.; for hips and ridges, 5 lbs. to 7 lbs.; for gutters and flats, or any place liable to be walked upon, 6 lbs. to 8 lbs.; for soil pipes, 7 lbs. or 8 lbs.; for lining sinks, 6 lbs. to 8 lbs. The weight in pounds per foot super. multiplied by 0·017 will give the thickness in decimals of an inch. For example, 8 lbs. lead is 0·136 in. thick, or a trifle over $\frac{1}{8}$ in. Lead pipes are made in a hydraulic press, the principle of which is shown in the figure. Molten lead, from which the scum has been removed, is contained in a steel cylinder having a rod standing up in the centre equal in diameter to the inside of the pipe. A ram above has a hole, or die, equal in diameter to the outside of the lead pipe to be made. When the lead has just set, either the cylinder is forced upwards or the ram is forced downwards by hydraulic pressure and the lead is squirted through the annular space between the die and the rod, to form a continuous pipe which is wound on a wooden drum. The following are the average weights of lead pipe, but great variation occurs: for instance, Farmiloe & Sons manufacture eleven thicknesses of $\frac{3}{4}$ in. pipe alone:

Bore in Inches.	Average weight in lbs. per yard.		
	Common.	Middling.	Strong.
$\frac{1}{2}$	3·20	4·40	5·20
$\frac{3}{4}$	4·80	5·60	7·20
1	6·00	8·00	9·20
$1\frac{1}{4}$	9·00	11·00	13·25
$1\frac{1}{2}$	12·00	14·00	17·50
2	16·80	21·00	24·90
$2\frac{1}{2}$	21·00	26·80	30·00

Lead pipes are sold in lengths as follows: $\frac{1}{4}$ in. to 1 in., in 15 ft. lengths or coils of 60 ft.; $1\frac{1}{4}$ in. to 2 in., in 12 ft. lengths and some of them in coils of 36 ft. Lead pipes must not be used for conveying soft water, as the oxygen of the air contained in small quantities in the water acts upon the lead, converting a portion into oxide of lead which is very poisonous and accumulates in the human system. Hard water does not have the same effect, as some of the carbonates contained are deposited on the lead and protect it. H. A.

Leaping Weirs.—Leaping or separating weirs were introduced by Mr. J. F. Bateman, F.R.S., on the Manchester Waterworks, and are now very generally adopted in various forms for the purpose of causing turbid and impure flood waters to be automatically rejected whilst the pure normal flow falls into a clear water conduit below the weir.

For example, when a mountain stream crosses an aqueduct the clear ordinary flow may be admitted to such aqueduct and the turbid flood flow rejected by constructing a weir (as illustrated) across the stream. It will be seen that the increased velocity of the water when the stream is swollen and discoloured in flood will cause it to leap over the comparatively narrow slot, giving access to the clear water conduit below, and flow down the stream to the river or compensation reservoir at a lower level. In the simplest forms of this device the width of the slot or opening is fixed once for all by experiment, but circumstances sometimes require that it should be made adjustable or capable of being entirely closed if required. Different forms will be found illustrated in the catalogues of makers of waterworks apparatus.



Leaping Weir.

Levelling, General Principles of.—Levelling is usually performed by means of a "dumpy" level consisting essentially of a spirit level combined with a small telescope, which, to save light, is fitted with a non-erecting eye-piece, so that objects viewed by it appear upside down; the optical axis of the telescope is adjusted to be truly horizontal when the bubble of the spirit level is in the centre of its run. There is also a small cross level by which the telescope may be levelled at right angles to its axis. Between the object glass and the eye-piece is placed a diaphragm, generally consisting of a glass plate with one central horizontal and two parallel vertical lines engraved upon it; these lines become visible in the field of view when the instrument is in focus. The telescope is mounted upon a tripod stand and can be turned about a vertical axis; the perpendicularity of this axis can be adjusted by milled screws, of which there are three or four, but preferably three, in order that the level may be made to revolve in a truly horizontal plane.

The other important instrument used in levelling is the staff. This is made in three pieces, the two upper portions sliding telescopically within the lower and fastening by spring catches; the height of the staff, when extended, is generally 14 ft. The face of the staff is painted in divisions of a foot, and also in tenths and hundredths of a foot—the feet are coloured red, the tenths black, and the hundredths are indicated by alternate lines and spaces.

In using a level it must be so adjusted that the bubble remains in the centre of its run in whatever position the telescope is turned. To set up a three-screw or "tribach" instrument, the tripod is firmly planted and the telescope placed in a line with two of the screws which are adjusted until the bubble in the large tube comes to the centre; then, without moving the telescope, the bubble of the cross level is brought to the centre by manipulating the third screw. This last process may slightly upset the first and render readjustment necessary; after this, the telescope should be rotated to prove the adjustment all round, and any final correction made with the large spirit level.

In setting up a four-screw level, the telescope is placed as level as possible and in line with two of the legs, and is first adjusted by the two screws which are parallel to it; it is then turned at right angles and adjusted in this direction by the other pair of screws, the process being repeated until the bubble remains stationary in whatever direction the telescope is pointed. The eye-piece must be focussed until the cross hairs or lines appear perfectly distinct in the field of view, and any

distant object, such as the figuring on the staff, sharply and steadily defined. The first adjustment is essential whenever the level is shifted, and the second if the distance from the staff is altered; others are occasionally required, but these two comprise all that is necessary when the level is in perfect order.

The staff must be held perfectly upright by an assistant so that its image may appear between the two vertical lines in the field of view; the upper edge of the horizontal line is the point at which all readings are taken.

The operation of levelling may now be considered. In a few words this consists in determining the variation in elevation of different points on the earth's surface from an assumed level line. Owing to the shape of the earth a truly level line would be a curve with its extremities equidistant from the earth's centre, whereas the line of "apparent" level, as set out by an instrument, would be tangential to the former line, and its divergence will be equal to the square of its length divided by the radius of the earth—both expressed in the same units; thus, at 1 mile the apparent level will be 8·007 in. above the true level, at 2 miles it will be 32·028 in., and so on.

Terrestrial refraction is another source of error; it is generally about one-seventh of the amount due to curvature.

As refraction causes objects to appear higher than they really are it reduces the correction required for curvature, so that the allowance for both will be represented by the difference. Although these corrections have in some cases to be made, in practical work the error can generally be neutralised by placing the level midway between the sighting stations.

The actual work of levelling is governed by the following rule:—

"Less staff" = a rise in ground; "More staff" = a fall.

To take a case of simple levelling; suppose it is required to find the difference of level between two points A and B. The level is set up about midway between the two and sighted upon the staff when standing upon the point A (we will suppose the reading to be 9·34 ft.); the staff is then transferred to point B, the level turned round and a reading taken, which we will assume to be 6·25 ft. B is obviously 3·09 ft. higher than A. It is almost superfluous to add that the height of the telescope makes no difference whatever.

Compound Levelling consists of a series of observations by which the undulations of the ground may be determined for any required distance. We will assume that it is necessary to take a line of levels through five points, A, B, C, D, and E. The level is set up, as before, between A and B and sighted on to the staff at A—this is called a "back" sight; it is then turned round and "fore" sighted on to B, both readings being noted in a special

Back Sight.	Intermediate.	Fore Sight.	Rise.	Fall.	Reduced Level.	Distance (on Chain).	Remarks.
10·72	—	—	—	—	142·20	—	A (Bench Mark) 142·20
—	9·63	—	1·09	—	143·29	—	B
9·34	—	11·51	—	1·88	141·41	—	C
7·80	—	9·55	—	0·21	141·20	—	D
—	—	12·40	—	4·60	136·60	—	E (Bench Mark) 136·6
27·86	—	33·45	1·09	6·69	—	—	
—	—	27·86	—	1·09	—	—	
		5·60		5·60			

"level" note book. After entering, each reading should be taken over again as a check. The staff is then carefully turned round to face point C, the level shifted and set up between C and D, and "back" and "fore" sights again taken and duly booked; the process is repeated

through the series. In ordinary work "intermediate" readings are taken, to do which the staff only is shifted; thus, if the distance from A to C was not more than, say, 250 ft., one might read from the level to B and again to C; in this case B would be an intermediate sight. A specimen of the bookings, with suppositious figures, is here given.

By starting at a given "datum" point and working back again to it, the accuracy of the levels may be checked; or, if the line be started on a Government "bench" mark (a broad arrow) ascertained from an ordnance survey sheet, and finished on another, a check is afforded; this has been assumed above, where it will be seen that the total fall (6·69 — 1·09) agrees with the difference in level of the bench marks.

Datum Line.—All levels are estimated with reference to a horizontal line, such as the ordnance "datum" (in Great Britain, the mean level of the sea at Liverpool), or any other altitude that may be convenient. In the above case of supposed levelling, point A is obviously 142·20 ft. above ordnance datum. To plot a line of levels, or "section," on paper, the datum is first drawn and the horizontal distances marked off to a convenient scale; the vertical lines are then erected from these points and the reduced levels are pricked thereon (for convenience of measurement a large scale is here adopted). The points are connected by a line which represents the surface of the ground.

Levelling may also be performed with the theodolite. (*See* "Surveying, General Principles of.")

Altitude may also be approximately determined by means of an aneroid barometer which indicates difference of level by registering the variation in atmospheric pressure.

The well-known principle that the boiling point of water varies with the atmospheric pressure, and therefore the altitude, is made use of in an instrument known as the "Hypsometer," which consists of a small boiler heated by a spirit lamp and fitted with a thermometer. This apparatus is sometimes employed as a check to the aneroid.

E. L. B.

Liernur Process of Sewage Removal and Disposal.—The Liernur process provides for the pneumatic removal and disposal by evaporation of the sewage of towns. The area to be drained is divided into districts, each provided with a "district reservoir," from which the sewage is pneumatically extracted and conveyed through 3½-in. and 4-in. iron pipes to a receiving reservoir at the central station by means of a vacuum pump maintaining a vacuum not exceeding half an atmosphere. The system is in use at Trouville, where, it is stated, the sewage is stored in a covered tank for about a week, mixed with sulphuric acid for the purpose of fixing the ammonia, heated in tubular boilers to 120° C., evaporated to a semi-solid state, and then reduced in a rotary chamber to a dry powder, the value of which is put at from £7 to £8. The process is worked by the Liernur Company at Trouville at an average annual charge of 16*s*. per house. The system was first applied at Amsterdam in 1871, and has been introduced at Leyden, Riga, and other places, including, more recently, Stansted in Essex.

Lighting.—(*See* "Acetylene," "Electricity," and "Gas.")

Lightning-Conductors.—Lightning is the sudden dissipation of electrical energy which has been stored between a thunder-cloud and the earth, or between one cloud and another, with a considerable difference of potential. It makes its own path, and forces its way through obstacles without regard to their electrical resistance. The function of a lightning-conductor is not so much to furnish a path for the flashes of lightning when they occur, as to dissipate the electrical energy as fast as it is generated, and thus prevent it from accumulating in dangerous quantities. With this in view a conductor should terminate

in a series of points to which the electricity may be attracted. The falling drops in a shower of rain also help to dissipate accumulations of electricity.

Where a great difference of potential exists between two clouds, culminating in an electrical discharge from one to the other, the charge in the lower cloud is liable to overflow suddenly to the earth, causing the so-called "B flash," against which lightning-rods afford little or no protection. It used to be considered that each lightning-rod formed the centre of a "protected cone," having a diameter at its base equal to the height of the rod, or even greater. Sir Oliver Lodge, however, is of opinion that there is no space near a rod which can be definitely styled an area of protection. A single rod does not afford adequate protection even for a chimney shaft, and a building can only be rendered absolutely safe from lightning by enclosing it in a network of wires like a birdcage. For practical purposes a reasonable degree of safety may be secured by placing two or more rods in suitable positions, and joining them by a horizontal conductor, to which any exposed metal-work and all prominently projecting parts of the building should be connected. From an electrical point of view iron is preferable to copper as a material for lightning-rods, the high conductivity of the latter being positively objectionable. Owing, however, to the rapidity with which iron oxidises, copper should be used for rods placed in inaccessible positions. A main conductor of iron should be built up of stout galvanized wire, and should weigh not less than 2½ lbs. per foot. A copper rod may consist either of tape or rope, and should weigh not less than 6 oz. per foot.

For subsidiary conductors smaller sections may be used. All joints should be as perfect as possible, both electrically and mechanically. The rods should not be insulated from the building, but should be secured by metal holdfasts. They should be arranged as far as possible in straight lines, sharp bends being highly dangerous. The foot of each rod should have a good earth connection in permanently damp soil. This may take the form either of a metal plate not less than 3 ft. square, or of a spike driven deep into the ground. All metal stove pipes should be connected to earth, as should also the columns of a steel-frame building. Cases of damage to a modern steel-frame structure are practically unknown.

The question of lightning-conductors was investigated by the "Lightning-Rod Conference" (1878—1881), and again by the "Lightning Research Committee" (1901—1905), who formulated a set of rules for guidance in the protection of buildings.

A. J. M.

Lime and Sulphate of Iron (Treatment of Sewage).—For the disposal of the Metropolitan sewage at Barking and Crossness, lime and sulphate of iron have been used as precipitants in tanks on the continuous flow principle for many years. Four grains of lime to one of sulphate of iron per gallon of sewage are the proportions used. An excess of lime is detrimental to the effluent as a portion of the suspended matters are rendered soluble thereby. (*See* "London Main Drainage.")

Lime Process (Treatment of Sewage).—Following the employment of Clark's process for treating water supplies, lime has been largely used as a precipitant for sewage, either alone or in conjunction with other materials. The purest lime, such as from the upper chalk or limestones of Derbyshire, should be used. It is added to the sewage in a perfectly caustic state in the proportion of 12 grains per gallon after a preliminary screening of the sewage. For the best results the lime should be in solution, and to this end it is first slaked with water and ground in a mortar mill or lime mixer to a finely divided or creamy condition. It is then thoroughly incorporated with the sewage by means of mechanical agitators, and the mixture allowed to settle for an hour, or longer if possible. Where

the quantity of sewage is large, however, the precipitating tanks are worked on the continuous principle. The resulting sludge, which is considerable in quantity, is periodically swept out of the tanks into sludge wells, and from thence pumped, gravitated, or otherwise conveyed to sludge lagoons to dry more or less, so that it may be employed as manure on land, or disposed of according to local circumstances. Sometimes it is pumped direct on to land, and steam-ploughed in, which is the most satisfactory method, as otherwise putrefaction soon sets in and gives rise to nuisance. Where no more economical means are available, it becomes necessary to reduce the bulk of the sludge by pressing out the water in sludge presses, but this costs about 2*s*. per ton of pressed sludge cake. The cost of the lime process is about 8*d*. per head of the population per annum. The method is in use at Wolverhampton, Willesden, Bury, Leyton, and many other places. The resulting effluent is alkaline, and a secondary decomposition sets in when discharged into rivers; the effluent is also destructive to fish life.

Lime. — Pure lime consists of a combination of the gas oxygen with the metal calcium forming an oxide of calcium, but neither calcium nor lime occurs in a natural state. The various limes of commerce are obtained by burning limestone, marble, chalk, or other substances, consisting chiefly of carbonate of lime, the carbon dioxide and moisture being driven off by the heat, causing a loss of weight of about one-half. There are various forms of lime, but the commonest are chalk lime, grey lime, and lias lime.

Chalk Lime is known as a fat or rich lime because it will bear the admixture of a large quantity of sand. When freshly burnt in the form of lump lime it will absorb a large quantity of water, disengage great heat, and swell into a bulky powder of hydrate of lime: this is the process of slaking. When mixed with sand and more water it is used for plastering, but not for mortar. It sets slowly by the evaporation of moisture, and hardens more slowly by the re-absorption of carbon dioxide from the air. It will not set in a damp situation, and is unsuitable for mortar, as it has so little ultimate strength.

Grey Lime, or stone lime, obtained by burning limestone or the lower chalk, is a "poor" lime, that is, it will not bear much sand added, owing to the greater proportion of inert matter contained, say 10 °/₀ to 30 °/₀, but it is a slightly hydraulic lime, because some of the impurity is clay, which gives it, when burnt, the property of setting in a damp situation. This lime slakes more sluggishly and with less disengagement of heat, but it sets more quickly and attains greater ultimate strength and hardness. It is used for mortar, say one part lime to two or three parts sand, but should not be used for plastering owing to the tendency to "blow" from the delayed slaking of certain hard-burnt particles.

Lias Lime is produced by burning the limestone from the lyas beds at Lyme Regis, Rugby, Bath, Aberthaw, &c. Owing to a large proportion of clay in its composition the lime produced is generally very hydraulic, and will even set under water. It takes a long time to slake, and should be ground either immediately after burning or while being made into mortar in a mortar mill. It makes good concrete in substitution for Portland cement, and is largely used for mortar for engineering works. It sets quicker than other varieties of lime and is much stronger.

Hydrated Lime.—Lime in its dry hydrated form, or slaked with just sufficient water for the purpose, is now becoming a marketable product in America. The advantages of hydrated lime are summed up as follows:—"Since it exists as a delicate white powder, and comes into commerce in sacks, it is more easy to handle and can be more accurately measured than the lump product. The method of handling this material resembles that of cement, and it requires no ageing after being mixed with water. Further, it does not deteriorate rapidly, and can be stored for a long time in any dry place without undergoing material changes, thus

doing away with the loss of lime due to spoiling and the danger of fire from the quick-lime coming in contact with water."

H. A.

Local Government Board Requirements: Cemeteries.—The requirements of the Local Government Board in regard to cemeteries from the sanitary standpoint can best be ascertained by reference to a memorandum issued by the Board dated December 13th, 1880. This memorandum begins by pointing out that the Public Health (Interments) Act, 1879, provides for an extension of the powers of Sanitary Authorities under the Public Health Act, 1875, so as to include the acquisition, construction, and maintenance of "a place for the interment of the dead, in the Act of 1879 called a Cemetery." It then goes on to say that in cases where the Sanitary Authority propose to defray the cost of establishing a cemetery by means of a loan the sanction of the Local Government Board becomes necessary (Public Health Act, 1875, s. 233). Among the points considered by the Board in each particular case, before granting their sanction to a loan for the purpose of a cemetery, the question as to whether the proposed site is suitable or unobjectionable from a sanitary point of view will find a place. The dangers to public health which will be considered are set forth as being the contamination (1) of air, and (2) of drinking-water; and the memorandum then proceeds to set forth the view taken by the Board as to the hygienic principles to be observed in the establishment of a cemetery. The memorandum above referred to should be read in conjunction with a circular of the Local Government Board dated August 19th, 1879, explanatory of the provisions of the Public Health (Interments) Act, 1879, and also a memorandum dated July, 1908, covering a set of model bye-laws with respect to the management of a cemetery. The Board also supply a form of queries to be filled up and of information to be furnished in connection with applications by Burial Authorities relative to the provision of new burial grounds. The form sets out in detail the various documents which must be forwarded in addition to the answers to the questions specified. The Board in loan applications require, *inter alia*, particulars in Form K, No. 2, as to existing indebtedness and assessable value of the district; and the periods allowable for repayment of loans are 60 years for purchase of freehold land, 30 years for erection of buildings, and 20 years for other work. The memorandum of July, 1908, sets out, *inter alia*, the requirements of the Board in regard to space, which will vary (as it is pointed out) according to the death-rate of the district. Taking average numbers in a stationary population of 1,000, there would be 19 deaths per annum, of which 7 would be under 12 years of age. This, on the basis of 4 sq. yds. for an adult and 2 for a child, would mean that 62 sq. yds. of ground is specified as a yearly requirement. These are the sizes recommended for grave spaces (*i.e.*, of the plots of ground each to contain one grave), into which the cemetery is to be divided. On the basis of paths occupying one-sixth of the available space, in one acre 4,033 sq. yds. would be available for grave spaces; and this, assuming a single interment in each grave, means that an acre of ground will serve a population of 1,000 for 65 years. Other details are set out somewhat voluminously, indicating diverse usages according to the nature of the soil, but these can best be understood by studying the memorandum itself.

W. M. F.

Local Government Board Requirements: Hospitals.—The control of the Local Government Board exercisable over local authorities in regard to hospitals arises in several ways, but chiefly through the usual medium of application for the borrowing of money by the local authority which can be provided for by section 69 of the Local Government Act, 1888, so far as County Councils are concerned, and by sections 233 and 234 of the Public Health Act, 1875, so far as other

authorities (extra metropolitan) are concerned, whilst London itself has its own Public Health Act, which deals with the subject. In regard to these applications, in addition to the usual particulars as to cost, plans, &c., the Local Government Board generally requires provision to be made for the repayment of any loans sanctioned by them for hospital purposes within the following periods:—

Land purchase (freehold) . .	60 years.
Buildings (permanent) . .	30 ,,
Heating apparatus . . .	30 ,,
Floating hospital . . .	30 ,,
Furniture	10 ,,
Ambulances and vans . . .	10 ,,

The Local Government Board has from time to time issued memoranda on the subject, and the most important of these is one dated May, 1902 (which can be obtained from the Government printers). It provides a great deal of useful and suggestive information as to some points which may be taken to be practically the requirements of the Local Government Board in regard to these hospitals. It has reference to isolation hospital accommodation, and it professes to be issued with a view to indicating to local authorities, more especially to those of districts of small or moderate size, the importance of providing hospital accommodation for the isolation of infectious cases and the means by which they may most advantageously make such provision. The principles it sets forth are said to be those which should be kept in view by all local authorities who propose to provide hospitals for their district by means of loans sanctioned by the Local Government Board. The memorandum goes on to deal with the subject of the area to be served and the size of the hospital in proportion to the population of the district; it further deals with the choice of a site and the erection of hospital buildings, and it includes plans of different types of ward-blocks, with especial reference to small-pox hospitals. This memorandum gives in the most accessible form the requirements of the Local Government Board as to hospital schemes. It should be stated that in this memorandum it is pointed out that the Local Government Board do not as a rule sanction loans for the erection of iron hospitals or any hospital buildings of a temporary character, except under special circumstances. With regard to cost of hospital schemes, some observations are made in the annual report of the Local Government Board for the year 1904—5. This is what the Board say:—"In connection with the borrowing of money by local authorities for hospital purposes, we have found that in many cases expenditure—sometimes of large amounts—has been incurred in excess of the loan sanctioned by us in respect of the scheme. In some instances this has resulted from under-estimating the cost; in others it has transpired that the arrangements which we approved in connection with the proposal for the original loan have been extended or otherwise varied without our consent. . . . . . It is important that ratepayers should know the probable cost of a proposed scheme before it is decided upon, and we trust that local authorities will do their best to see that the estimates which accompany their proposals are as accurate and as complete as they can be made . . . . . No material alteration should be made without our consent in the plans of works in respect of which we have sanctioned the borrowing of money. In some cases we have found that departures from hospital plans provided by us have involved expenditure which we could only regard as needless or extravagant; we have in these cases declined to allow the additional expense to be defrayed out of loan monies."

The memorandum of May, 1902, referred to above gives specific details in regard to accommodation. Thus, in the ward-blocks each bed should have at least 12 lin. ft. of wall space, 144 sq. ft. of floor space, and 2,000 cu. ft. of air space; in calculating the latter, any height of wards above 13 ft. should not be taken into account. All inner surfaces (of walls, floor, &c.) to be non-dust-harbouring. Ventilation to be by windows on opposite sides, constructed with double-hung sashes

and hopper fanlight falling inward with side cheeks. Area of windows proportioned as 1 sq. ft. to every 70 cu. ft. of ward space. Windows to face south-east and north-west respectively. Closets and slop-sinks to be placed in annexes separated from the wards by cross-ventilated lobbies. Instructions are also given as to other buildings. At least 40 ft. must be left between any building which is to contain infected persons or things and any other buildings. The drains of each block must be trapped from the common drain and ventilated separately by an inlet just above the trap and by ventilating shafts at their highest points. Three most excellent plans, setting forth all these and numerous other details, accompany the memorandum. There has also been published, under date of March, 1908, an appendix to this memorandum, containing a fourth plan for an observation block. In this provision is made for 1,440 cu. ft. of air-space per bed in lieu of 2,000 in view of other improvements in construction. W. M. F.

Local Government Board Requirements: Loans. — The principal bodies concerned in the raising of loans for sanitary purposes are, (1) county councils, (2) municipal corporations, (3) urban and rural district councils, and (4) parish councils. In addition to these principal bodies, lesser public or semi-public bodies, such as burial boards and port sanitary authorities, are also invested with borrowing powers, subject to the control of the Local Government Board.

The raising of loans and their repayment is subject in part to statutory provisions and in part to departmental control. Thus, the Local Government Act, 1888, by which county councils were created, sets out the purposes for which and the conditions under which a county council may borrow money; similarly, the Municipal Corporations Act, 1882 (amended by the Local Government Act, 1888), provides for borrowing by town councils, whilst the Public Health Act, 1875, and subsequent amending Acts provide for the loan necessities of urban and rural district councils. Parish councils derive their borrowing powers from the Local Government Act, 1894; and the other authorities named, from the Burial Acts and other measures particularly affecting their existence.

Loans may be raised only with the concurrence of the Local Government Board into whose hands the revisionary powers formerly exercised by the Treasury and all recently constituted new powers have been placed. There are three methods in which loans can be raised, *i.e.*, (1) by the issue of stock, (2) by mortgage, and (3) by borrowing from the Public Works Loan Commissioners. The issue of stock by local bodies is provided for mainly by the Local Government Act, 1888, and by the Public Health Acts Amendment Act, 1890. Under both these Acts the Local Government Board are authorised to issue regulations, and such have been issued, and are in operation, under dates 1891, 1897, and 1901, and appear under the two headings of County Stock Regulations and Stock Regulations respectively. They deal with the issue of stock in every detail, and should be consulted whenever particulars are required. As regards mortgages, these are governed by the Commissioners Clauses Act, 1847, and have reference to the security which the persons termed Commissioners entrusted with powers to carry out authorised works may give for the loans they obtain. The provisions of this Act have been incorporated into many local Acts, and also Acts (like the Burial Acts) which apply generally. In regard to loans obtained from the Public Works Loan Commissioners, who are a body brought into existence by the Public Works Loans Act of 1875, it may be said that the schedule to that Act specifies the purposes for which the Commissioners are empowered to lend money, and to this list of purposes from time to time additions are made in and by Acts of Parliament passed for new objects or to expand existing objects of national importance. Thus, the Commissioners may lend money to local authorities

whose districts do not exceed in rateable value individually £200,000, for such purposes as the provision of allotments, the carrying on of education (elementary and higher), the purposes of the Public Health Acts, and the provision of small dwellings for the working classes. The rules under which the Commissioners lend money include stipulations that the works or undertakings shall be entirely new, and that the power of borrowing which is being exercised shall not have been so exercised before. Money required for the purpose of repaying an old loan cannot be obtained from the Commissioners; and repayment is generally specified under an annual system extending for a period not exceeding 30 years. (For powers to borrow for specific purposes, see the various articles under separate headings). W. M. F.

Local Government Board Requirements: Mortuaries.—In dealing with applications for loans by local authorities for the purpose of providing mortuaries, the Local Government Board gives some assistance. They have provided a set of model bye-laws under section 141 of the Public Health Act, 1875. This set is numbered XV. Mortuaries, dated 1896, and copies (price 2*d.*) can be purchased from the Government printers. To these model bye-laws is appended a memorandum dated 25th July, 1882, with observations by the Local Government Board as to the extent to which local authorities ought to avail themselves of their power to make proper provision for dealing with dead bodies which come under their care, and including suggestions as to the erection of mortuary buildings, and their general management. Sanitary authorities when desirous of raising loans for such purposes must obtain the sanction of the Local Government Board, and that sanction may be taken to depend upon the adoption of the suggestions contained in the Memorandum of 1882, beyond which the most important consideration is that of drainage, and in regard to this the Board should first be consulted. Thirty years is the usual period allowed for repayment of loans for buildings of this class outside the Metropolis. It should be observed that outside the Metropolis local authorities have no statutory power to provide buildings in which to hold coroners' inquests, but are in a position to grant the use of portions of existing buildings for that purpose.

The requirements (or "suggestions") of the Board as to site and structure of mortuaries are given in the Memorandum XV. referred to above. Buildings should be concealed from public view; external architecture to "serve to convey the impression of due respect for the dead." Every chamber intended for the reception of corpses to be on the ground floor; in addition a waiting-room for visitors and for the use of mourners assembling, a caretaker's house, and a shed or outhouse for the keeping of shells and other appliances. The mortuary chamber to have a ceiling, or, if open to the roof, a double roof to be put in with a space of 8 in. between each covering. Louvres or air-gratings for ventilation under the eaves. Windows on the north side; if necessary elsewhere, to be fitted with external louvre blinds. Cement floors preferable. Water to be laid on with a tap in the chamber. Shelves and tables preferably to be made of slate slabs, and to be placed so that their upper surfaces may be from 2½ to 3 ft. above the floor. Two chambers to be provided—one being for infectious cases, and this should be placed as far as possible away from the other. The entrance to each chamber to be direct, without any intervening passage. These principles are very clearly set out in the plan which accompanies the memorandum.

W. M. F.

Local Government Board Requirements: Sewage and Sewage Disposal.—When a local authority is proposing to inaugurate some scheme of sewerage or of sewage disposal which will involve the borrowing of money under the provisions of sections 233 to 235 of the Public Health Act, 1875, the sanction of the Local Government Board must be obtained,

and in order to obtain that sanction the scheme which the local authority is proposing to adopt must be submitted in detail for the approval of the Local Government Board. If, however, such a scheme does not involve the borrowing of money, it will not be necessary to seek any such approval, though, of course, the general powers of intervention by the Board remain. The Local Government Board do not favour any particular scheme, but leave it to the local authority to consult their own engineers and formulate such a scheme as appears to them to be suited to the requirements of their own particular district. Such schemes naturally vary considerably, but as there is no fixed scheme, and as there are no specific plans recommended for adoption by the Local Government Board, it is only necessary that the scheme propounded and submitted should conform to certain general requirements. The scheme, whatever it may be, must be definitely adopted and approved by the local authority before it is submitted to the Local Government Board. The general requirements of the Board fall practically under three headings:

1. Requirements as to the period fixed for repayment of the proposed loan.

2. Certain undefined suggestions made from time to time in the annual reports and the published correspondence of the Local Government Board.

3. Certain definite requirements set out in the form of estimate (K. No. 29).

As to Periods of Repayment.—The following is taken from the Report of the Select Committee on Repayment of Loans (1902) as being a list of the periods usually allowed by the Local Government Board for the repayment of loans sanctioned for sewage purposes:—

Land Purchase	60 years.
Sewers and surface water drains and such ordinary works as tanks, filters, &c.	30 years.
Sewage Lifts	30 years.
Ejectors	15 years.
Polarite	10 years.
Sludge Presses	10 years.
Farming Stock	5 to 10 years.

For general observations on this topic see Local Government Board Report, 1906-7.

Indefinite Suggestions amounting more or less to Requirements.—These are both varied and numerous, and they include such general principles as concern estimated costs, employment of engineers, the adoption of competitive schemes, and the management or supervision of sewage-disposal works. In regard to the last-named, the Board favour the retention by local authorities of this management in their own hands (but see Local Government Board Annual Report for 1902-3, where special reference is made to the need for skilled supervision). In dealing with applications to sanction loans for sewerage purposes, the Local Government Board require not only full and complete details and plans, but also a variety of miscellaneous information as to rateable value of the district where the loan is to be repaid from, and satisfactory proof of all necessary consents having been obtained, together with details of existing works proposed to be superseded, in respect of which there may be a portion of an earlier loan still outstanding.

Definite Requirements.—These are mostly set out in the form of estimate (K. No. 29), but not entirely so. They may be expressed, however, in the following classification[1]:—

I. *Sewers*.—(*a*) In the case of brick sewers, radiated bricks to be used when obtainable.

(*b*) Side junctions for house drains to be inserted in brick sewers at the time of construction. Junction pipes to be provided on all pipe sewers.

(*c*) Main sewers as far as practicable to be laid at such depth and with such gradients as to afford means for draining the cellars and basements of houses.

(*d*) Sewers laid under roadways to have at least 4 ft. of cover between the top of the pipes and the surface of the horse-road; but when this is impracticable the pipes to have

[1] Extracted from Wood and Johnson's "Encyclopædia of Local Government Board Requirements," Vol. II., Part 57, where the details are very fully set out.

a 6-in. coating of concrete. This latter requirement applies also where the pipes are laid in the roadways at a depth exceeding 15 ft. Where they are laid under fields there is to be at least 3 ft. of cover.

(*e*) Sewers to be laid in straight lines with manholes at all changes of direction or gradient, and no two manholes to be more than 100 yards apart.

(*f*) All manholes and underground chambers in roadways to be of sufficient strength to carry the heaviest traction engine or other traffic likely to pass over them.

(*g*) All joints to be of cement and not clay.

(*h*) Efficient ventilation to be provided.

(*i*) Adequate measures to be adopted for preventing the infiltration of sub-soil and surface water into the sewers.

(*j*) A storm overflow to be constructed in such a way as not to come into operation until the ordinary dry weather flow of sewage has been diluted with five times its volume of storm water.

II. *Machinery.*—All pumping machinery to be provided in duplicate.

III. *Sewage Disposal.*—The requirements of the Local Government Board here depend upon whether the scheme submitted to them is one which involves the discharge of sewage matter into non-tidal rivers. If it does it must include proper provision for the purification of the sewage upon an adequate area of land, in addition to any preliminary treatment it may undergo, and this will be insisted upon unless it can be shown that land suitable for the purpose cannot be obtained. With regard to the area required, this will vary in different cases, and will depend not only upon the quality of the sewage, but also upon the nature of the land available, and further, upon the details of the preliminary process suggested. Where, however, it is only proposed to deal with domestic sewage and land is available, the Local Government Board require as a minimum the following proportions of area per population :—

Broad irrigation (without any previous treatment) one acre of land to every 150 persons of the population of the area to be drained.

Irrigation after bacterial process, one acre to every 1,000 persons, or one acre to every 30,000 gallons of drainage.

Other methods, one acre to every 1,000 or 2,000 persons according to the system proposed to be adopted.

Where it is intended to construct bacteria beds for sewage treatment, the following requirements are also specified :—

(*a*) The beds must be large enough to deal with twice or three times the dry weather flow of sewage according as the district may or may not have a separate surface water drainage system.

(*b*) Where the beds are to be worked on the contact principle and the sewage is to be finally treated on land, one, *i.e.*, single contact, will suffice. The working capacity of the beds will be taken at one-third of the capacity of the tanks after the filtering material has been put in, and there must not be more than three fillings in 24 hours.

(*c*) Where the filters are to be worked on a percolating principle and land treatment is provided, the maximum rate of filtration must not exceed 56 gallons per square yard per foot in depth of filtering material per day.

(*d*) Where land treatment is impossible the cubic contents of the filtering matter in either case must be double what is indicated under (*b*) and (*c*).

(*e*) Provision must be made, in addition to what has already been provided for the dry weather flow, for dealing with up to at least six times its volume by providing extra land or by passing it through storm water filters capable of admitting a continual rate of filtration not exceeding 500 gallons per square yard per day.

(*f*) Where septic tanks are to be provided, their capacity should not be less than the ordinary daily dry weather flow of sewage to the outfall.

Special requirements have to be considered in regard to applications by local authorities to the Local Government Board for sanction

to loans under section 32 of the Public Health Act, 1875, for the construction of works outside the district of the local authority. In a case of this kind it is usual for the Local Government Board not to make an inquiry until the time has expired during which objections may be lodged in order to avoid the unnecessary expense of having a further inquiry later on. In urgent cases, however, and if there is not much likelihood of objections being made, the Local Government Board will, on application, arrange for an inquiry to be held without waiting for the usual time to expire. This inquiry having been held, the period of objection must be allowed to expire and the matter can then be dealt with immediately. A copy of the statutory declaration required, also copies of the newspapers containing the necessary advertisements, should be forwarded. If no objection has been made, the fact should be stated; but if any objection has been made, a resolution must be passed and a copy of it be forwarded requesting the Local Government Board to appoint an inspector to make further inquiry and report. W. M. F.

Local Government Board Requirements: Water Supply.—Under the provisions of the Public Health Act, 1875, certain local authorities are empowered to construct and maintain waterworks and take over and lease or hire waterworks and to contract with any person or persons for water supplies; but if they wish to purchase any waterworks or any right to take over or convey water, either within or without their district, they must obtain the sanction of the Local Government Board. In fact, it comes to this, that when a local authority wishes to raise money for the purpose of providing a water supply, the Local Government Board will have to be consulted, and then there are certain requirements which will have to be complied with. The Local Government Board do not specify what these requirements are, although they supply an official form of estimate (K. No. 20), in which the local authority should set forth full details of the estimated cos' of the scheme. It is understood that although they do not publish any special information, nor do they issue any plans for the guidance of the local authorities, or do anything else to furnish in a succinct form the particular requirements to be met, they do have regard to various matters which they deal with on general lines. Their requirements may be brought practically under two headings:—

(1.) As to the financial aspect of the proposed scheme; and

(2.) As to the practicability or sufficiency of the proposed supply.

(1.) Of course the Board go very fully into the financial aspects of the matter, and apart from the provisions of the Public Health Act, 1875, and the Public Health (Water) Act, 1878, with regard to the incidence of expenses, they consider carefully the whole subject of cost in the interests of the ratepayers of the area so affected. Then as to the repayment of proposed loans, the following are the periods allowed for such repayments in the case of loans sanctioned for the water supply purposed:—

Purchase of land (freehold) . .	60 years.
Mains and pipes	30 ,,
Reservoirs	30 ,,
Water towers	30 ,,
Purchase of existing undertakings.	30 ,,
Machinery	15 ,,
Waste water meters . . .	10 ,,
Boring experiments . . .	5 ,,

It should be pointed out that a local authority may apply for loans in respect of three different schemes, that is to say, for the carrying out of purely experimental works, or for the taking over of existing waterworks, or for the construction of new works entirely.

(2.) As to the Projected Supply.—The Local Government Board require first of all that any scheme shall provide if possible for not less than the undermentioned quantities per day per head of the population:—

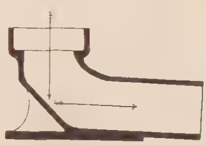
10 to 15 gallons in agricultural villages;

16 to 20 gallons in non-manufacturing towns;

20 to 30 gallons in manufacturing towns.

As regards the laying of mains, cast-iron pipes should be used, not galvanized, iron, stone or earthenware, and the mains should be laid at a depth of not less than 3 ft. from the surface reckoned from the top of the pipe, and should be at least 3 in. in diameter except there be special reasons. Hydrants to be provided at all dead ends. Screw-down hydrants are to be used in preference to ball hydrants. The pumping machinery to be provided in duplicate; and all sources of supply, reservoirs, and the like to be protected by unclimbable fencing. W. M. F.

"**Loco" Apparatus.**—A series of drainage appliances—bends, traps, &c.—designed by Mr. F. C. Lynde, C.E. The principle underlying these apparatus is the law of deflection. With this purpose in view the bends, &c., are made with flat striking surfaces in the interior, so arranged that water, &c., falling upon these vertically will be deflected down the horizontal drain, without, it is claimed, loss of flushing power. The principle involved is made clear in the accompanying illustration which is a longitudinal section through a "Loco" bend.

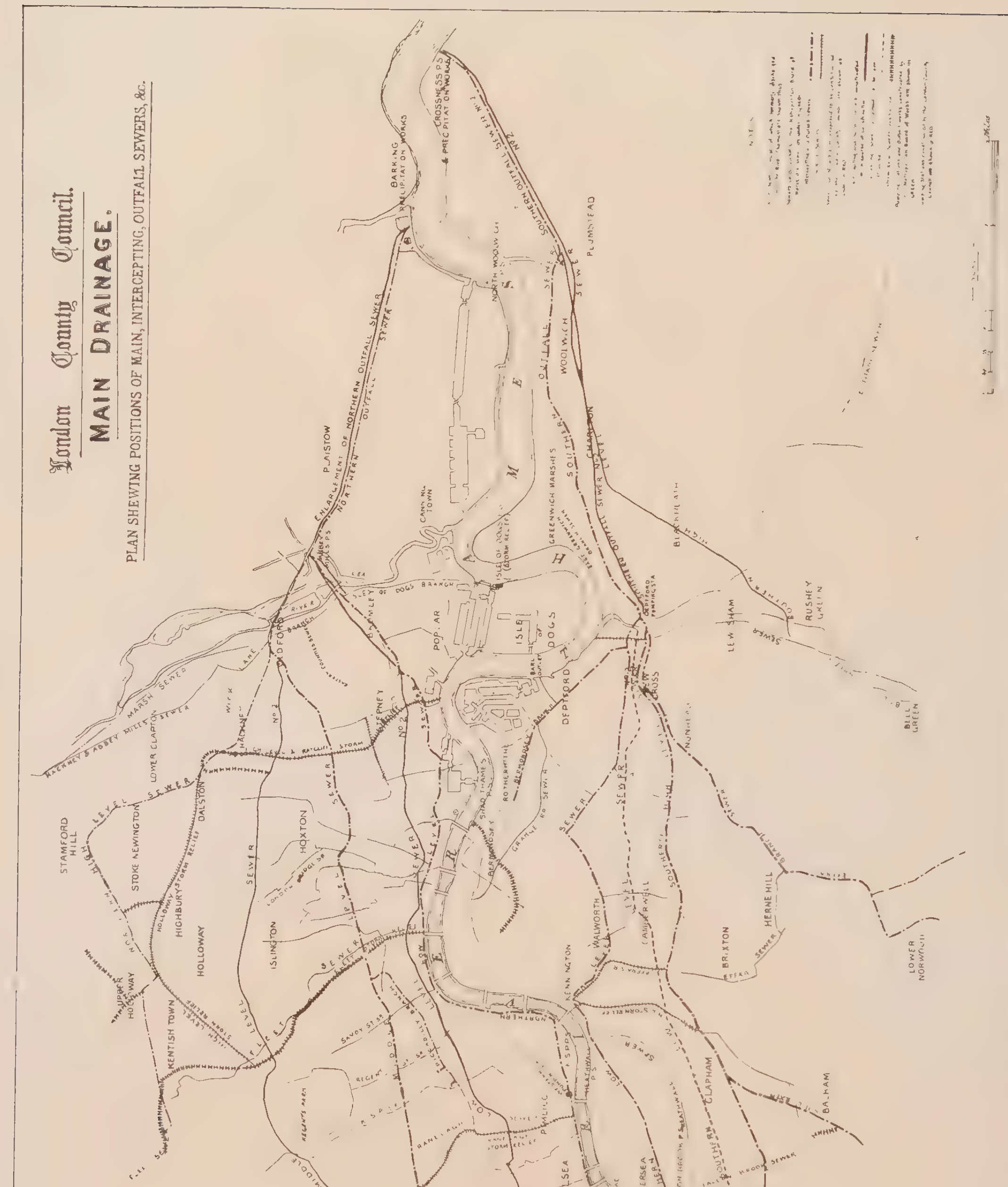


"Loco" Apparatus.

London Main Drainage. — The first sewers in London consisted of the natural watercourses, ditches, &c., which were covered in and converted into sewers for the carriage of surface waters only. Water-closets were introduced about 1810; but they had to be made to discharge into cesspits, as it was, up to the year 1815, a penal offence to discharge polluting matters into the sewers. Prior to 1847 the sewers of London were under the management of eight different Commissions; but in that year they were superseded by one general Commission termed "The Metropolitan Commission of Sewers," the members of which directed their attention mainly to a consideration of the kinds of sewers to be adopted and to the abolition of cess-pits. In 1847 an Act was passed making it compulsory to discharge house drains into the sewers, the result of which was that within about 6 years 30,000 cesspools were abolished, and the whole of the sewage of London was turned into the Thames. The river, naturally, soon became very foul, and between the years 1849 and 1854 no less than five different Commissions were formed to deal with the evils arising out of this new state of affairs. In 1856 the Metropolitan Board of Works came into being under the powers of the Metropolis Management Act of 1855.

One of the first acts of the new Board was to attempt the complete interception of the sewage so as to discharge it into the river below London and beyond the boundaries of the metropolis. This they did by constructing intercepting sewers parallel to the river, into which the existing main sewers were connected. These conveyed the sewage on the north side to Barking, and on the south side to Crossness. Three intercepting sewers were constructed on the north side, the low-level, middle-level, and the high-level. The high and middle-level sewers conveyed the sewage by gravitation to Old Ford, from where they ran together as far as Abbey Mills, at which point the sewage from the low-level sewer is pumped into them, after having been already raised once at the Western Pumping Station at Pimlico. From Abbey Mills the sewage is conveyed to Barking by gravitation in what is known as the northern outfall.

On the south side of the river there are also three intercepting sewers—the low-level, high-level, and the Effra branch sewer. The high-level and the Effra branch sewers convey the sewage by gravitation to Deptford, at which point the sewage from the low-level sewer is pumped into them. From here the sewage is conveyed by gravitation in the southern outfall sewer to Crossness, where the whole of the sewage has to be pumped. Storm overflow weirs were constructed at the junctions of the old main sewers with the intercepting sewers, so that if heavy rains should cause the


London County Council.
MAIN DRAINAGE.
PLAN SHEWING POSITIONS OF MAIN, INTERCEPTING, OUTFALL SEWERS, &c.
BARKING
CROSSNESS
PLAISTOW
NORTHERN OUTFALL SEWER
SOUTHERN OUTFALL SEWER
CANNING TOWN
ISLE OF DOGS
POPLAR
GREENWICH MARSHES
WOOLWICH
PLUMSTEAD
DEPTFORD
BLACKHEATH
LEWISHAM
RUSHEY GREEN
BELL GREEN
STAMFORD HILL
STOKE NEWINGTON
LOWER CLAPTON
DALSTON
HIGHBURY
HOLLOWAY
UPPER HOLLOWAY
KENTISH TOWN
ISLINGTON
HOXTON
HACKNEY
HIGH LEVEL SEWER
MARSH SEWER
KENNINGTON
WALWORTH
CAMBERWELL
BRIXTON
HERNE HILL
LOWER NORWOOD
CLAPHAM
BALHAM
BATTERSEA
CHELSEA
BROMPTON
KENSINGTON
NOTTING HILL
BAYSWATER
PADDINGTON
KILBURN
SHEPHERDS BUSH
HAMMERSMITH
EAST ACTON
CHISWICK
BARNES
FULHAM
PUTNEY
WANDSWORTH
COUNTER'S CREEK
WOOD LANE
THAMES

flow in the latter to become excessive it could overflow into the old sewers, and thus go direct into the Thames.

The construction of the intercepting sewers effected a great improvement, not only by removing the sewage to a distance before it was discharged into the river, but also by reducing the amount of flooding in low-lying areas that had formerly taken place. Under the old system the main sewers were only able to discharge their contents at or about the level of low water, the rise of the tide closing the outlets, with the result that any sewage flowing down during the period the outlets were closed was pounded back in the main sewers. In times of heavy and long-continued rain, and more particularly when such occurred at the time of high water in the river, the closed sewers were unable to store the increased volume of sewage, which then rose through the house drains and flooded the basements of the houses. This being the case, it will be seen that the provision made for discharging excessive rainfall by means of the old sewers could not be satisfactory at all times. Under these circumstances the Metropolitan Board of Works, in 1879, decided to carry out the following flood relief works :—

(1.) Storm relief line for the Ranelagh and King's Scholars' Pond sewers.

(2.) Storm relief line for the Ratcliffe Highway and Limekiln Dock sewers.

(3.) Relief line for the high-level sewers at Hackney.

(4.) Intercepting sewer from Putney to Clapham.

(5.) Storm relief to high-level at High Street, Clapham, to discharge into Effra Creek, Vauxhall.

(6.) Deptford, storm overflow.

(7.) Sewer from Lee Bridge to Deptford.

(8.) Sewer to relieve low-lying ground at Walworth.

(9.) Storm sewer to relieve Holloway and Kentish Town.

The total estimated cost of these works amounted to £708,000, and all the sewers were constructed with the exception of the sewer at Walworth; but a relief sewer was made from Rotherhithe New Road to Southwark, known as the Grange Road sewer.

In 1897 the Main Drainage Committee of the London County Council, who took over the control of the sewers of the metropolis in 1889, instructed their engineer, Sir Alexander Binnie, to consider the whole main drainage system, with the result that he reported that the following works were the most urgent :—

North Side of River.—Two sewers, Old Ford to Barking; new middle-level sewer, Paddington to Old Ford; new low-level sewer, Hammersmith to Bow; extension of middle-level sewer to Scrubb's Lane, Willesden; pumping machinery at Abbey Mills.

South Side of River.—Low-level sewer, Deptford to Crossness; high-level sewer, Catford to Crossness; low-level sewer, Battersea to Deptford.

The total estimated cost of these works amounted to £2,947,000. The greater part of them have been constructed, some are in progress, and others nearly ready for contract. In addition to these works, six pumping stations were constructed to relieve the low-lying intercepting sewers—three on the north side of the river at Lot's Road, King's Scholars' Pond, and Isle of Dogs; and three on the south side—at Falcon Brook, Heathwall, and Shad Thames.

The new sewers already in operation have greatly diminished the number of discharges of rainfall into the Thames within the County of London, but in spite of their construction a considerable amount of flooding occurred in many parts of London in 1903, when a total of 35 in. of rain fell. The Main Drainage Committee of the London County Council therefore decided in 1904 to carry out the following additional flood relief works at a total estimated cost of £737,000.

Suggested Flood Relief Works.—North Side: (1) Storm relief sewer, Holloway to the Thames; (2) storm relief sewer from middle-level sewer to Counters Creek sewer (North Kensington storm relief sewer); (3) extension

of Hackney Wick relief sewer, northwards; (4) Stroud Green storm relief sewer.

South Side: (5) Storm water-pumping station at Wandsworth (the Falcon Brook station already mentioned); (6) new sewers in connection with the above pumping station; (7) storm water pumping station to deal with storm water in Southwark and Bermondsey (the Shad Thames station already mentioned); (8) Southwark and Bermondsey storm relief sewer.

Some of these works have been completed and others are in course of construction. The bulk of the rainwater carried by the sewers is now taken to the outfalls and treated before it is discharged, and there will be a still further improvement in this respect as soon as the completed scheme comes into operation.

The total discharging capacity of the outfalls and storm water pumping stations on both sides of the river, not including the discharging capacity of those storm relief sewers which act by gravitation, is 1,464,000,000 gallons per 24 hours.

The average dry weather flow per 24 hours amounted in 1908 to 283,000,000 gallons, so that provision has been made to deal with 1,181,000,000 gallons of storm water per 24 hours, apart from the capacity of the relief sewers discharging direct into the river. This is equivalent to a rainfall of about 0·70 in. over the whole area of the metropolis in 24 hours.

Originally the whole of the sewage was stored at the Barking and Crossness outfalls during the flood tide and discharged on the ebb tide in its crude state. In 1887, however, the Metropolitan Board of Works commenced the construction of precipitation works at Barking, and in 1888 at Crossness. The sewage when it arrives at the works is subjected to chemical treatment: the addition of 1 grain of proto-sulphate of iron (ferrous sulphate) and 4 grains of lime to every gallon of crude sewage. The precipitation takes place in long channels. The sewage flows in at one end of each channel, and after the heavier matters are precipitated the clarified sewage goes over a weir at the other end of the channel into the river. After a certain period each channel is shut from the inlet of sewage, and the heavier matter left in the channel is dealt with in the following manner. The water is run off from the channels by means of floating arms, and the wet sludge is pushed through screens by hand into a sump. From this it is pumped into sludge-settling channels where it remains for about 24 hours. The supernatant water on the top of the settled sludge is drawn off by means of telescopic weirs, and is treated with 20 grains of lime and 10 grains of iron per gallon, afterwards being pumped up to the outfall sewer to mix with the rest of the sewage. The clarified liquid is discharged continuously into the river at all states of the tide. The settled sludge gravitates to a sludge store, from which it is pumped into sludge ships which take it out to sea and deposit it at Black Deep in the estuary of the Thames, over a distance of from 8 to 10 miles. Six sludge vessels are constantly employed for this work, each holding about 1,000 tons, and about 8,200 tons of sludge are disposed of per diem.

The area draining into the Council's sewers in 1901 was about 140 sq. miles, and the population was 5,136,192 persons. The discharging power of the northern outfall sewer at Barking under present conditions is about 500,000,000 gallons, and of the southern outfalls at Crossness, 513,000,000 gallons per 24 hours. The permanent staff employed in cleansing the sewers at the pumping stations and outfall works, and on the sludge boats varies from 900 to 1,000 men.

The total length of the main, intercepting, and outfall sewers, when those in course of construction and those about to be constructed have been completed, will be nearly 352 miles. The net capital expenditure on the sewers and works of sewerage up to March, 1909, has been £11,110,389, and it is estimated that an additional expenditure of about £1,500,000 will be required to complete the schemes already sanctioned by the Council.

Much of the information given above has been obtained from a report which was prepared for the Council by their engineer, Mr. Maurice Fitzmaurice, C.M.G., M.A., M.Inst.C.E., from which the accompanying plan has also been reproduced. H. C. H. S.

London Water Supply.—London is supplied with water from several sources and by many works, formerly under the control of separate waterworks companies, but now under the control of the Metropolitan Water Board. The sources of supply are four in number (1) the river Thames, (2) the river Lea, (3) natural springs, and (4) wells sunk in the chalk or other strata in the Lea Valley, on the North of the Thames, in Kent, and at certain other places South of the Thames.

Speaking roughly about 56 °/₀ of the total supply of London is drawn direct from the Thames, 20 °/₀ from the Lea, 14 °/₀ from springs and wells in the Lea Valley, 9 °/₀ from wells in Kent, and 1 °/₀ from wells in the southern district.

The total population served by the London mains is about 7,000,000 persons, the exact total being 6,943,412 as stated in the annual report of the Metropolitan Water Board for the year ending March 31, 1908.

The bulk of the London water supply being drawn from the Thames and Lea has to be purified before it reaches the consumer. The methods of purification adopted are (*a*) natural purification by storage and subsidence in open reservoirs of large capacity, and (*b*) filtration after storage. The storage reservoirs are generally formed by enclosing large areas with earthwork embankments made watertight by means of thick core walls of puddled clay. The filters are constructed of sand laid upon gravel and large stones above a false bottom so as to ensure ample drainage. The water after filtration is pumped to service reservoirs which are generally roofed in order to protect the water from dust and foreign matters, and also from the action of the sunlight which, though beneficial to purification in the open storage reservoirs, would be apt to produce a growth of green weed in the hard London water which would render it unsuitable for drinking purposes. The water which is derived from purer sources, such as wells, is pumped direct to the service reservoirs, and in some cases the well water and the filtered river waters are mixed.

The service reservoirs are situated as far as possible at such levels as will supply a district or area by gravitation. Where it is impossible or inexpedient to make the high-level service reservoir large enough to hold many hours' supply for its district a larger service reservoir is made at a lower level, and from it the high-level reservoir is supplied by pumping. The high-level reservoir in this case is sometimes merely a device for keeping the pressure in the service mains constant, the real immediate source of supply being the reservoir at the lower level. The water thus obtained and stored is distributed in cast-iron mains of sizes which vary from 54 in. diameter as a maximum to 2 in. diameter as a minimum. These mains are governed by means of sluice valves in such a manner that any whole district, section, main or branch pipe can be shut off in case of need. Hydrants for fire and other purposes are connected to the mains in the streets and elsewhere, and separate connecting pipes—one for each house—convey the water to the houses; each service pipe is governed by its own valve or stop-cock outside the property to which it conveys water. No other waterworks system in the world is comparable with that of London. The vast character of the works under the control of the Metropolitan Water Board may be gathered from the following figures which are taken from the annual report of the Metropolitan Water Board for the year ending March 31, 1908. In that year over 80,000,000,000 gallons of water were consumed in London, the average daily supply being 219,000,000 gallons. The average daily supply per head was 32·84 gallons. There were then 62 reservoirs for storage and subsidence holding 8,913,600,000 gallons, or

about 40 days' supply, and in addition to this another 6,000,000,000 gallons storage was authorised, and in immediate contemplation, the works for which have since been put in hand, the reservoirs at Walton having been opened, and those at Chingford to hold 5,000,000,000 gallons having been commenced. Besides the storage reservoirs, the report already quoted describes 78 service reservoirs holding in all 243,000,142,000 gallons. The filters were 161 in number and covered an area of 161·91 acres. There were 37 pumping stations containing 257 engines having a total horse-power of 34,645, while some of the pumps were lifting water to a height of 600 ft. There were 6,116 miles of water main and 66,809 hydrants. The use to which these hydrants are put may be understood from the fact that during the year in question there were no fewer than 2,800 fires in the area of the Metropolitan Water Board.

The Board have divided their area into five engineering districts:—

1. The Eastern district deriving its supply from the rivers Thames and Lea and from eleven wells in the Lea Valley.

2. The Kent district, which is independent of the Thames and Lea, being supplied solely from deep wells.

3. The New River district deriving its supply from the river Lea, the Chadwell spring, and from 18 wells in the Lea Valley, most of which feed the New River Channel, and also from the Thames by intercommunication; a small supply for non-domestic purposes is also obtained from the Hampstead and Highgate Ponds.

4. The Southern district, which derives its main supply from the Thames with a supplementary source from wells at Selhurst, Streatham, Honor Oak, and Merton Abbey.

5. The Western district, which is supplied only from the Thames.

The intakes on the river Thames are situated at Walton and Molesey. Those upon the river Lea are at Enfield Lock, and the intake of the New River district is situated between Hertford and Ware Locks on the river Lea. The present policy of the Water Board is to increase the storage capacity by constructing reservoirs, and for this reason very large works are in contemplation and in progress. The demand for water is growing; the present supply is limited and the opinion is held that the increase in population will eventually render resort to some other source than the Thames watershed imperative. It, therefore, is necessary to provide storage reservoirs in order to intercept as much water as possible at times when the rivers are full; but there is another very important reason why a policy of constructing additional storage reservoirs has been adopted, namely, that the water in the Thames and Lea is of such a quality that it requires considerable purification, and it is essential to do everything possible to guard against harmful germs, which may be present in the river waters, finding their way into the London mains. That the measures adopted are successful can be best proved by practical results, inasmuch as the general health in London is good.

Dr. Houston, the Board's Director of Water Examinations, reported to the Board to the effect that bacteriologists were agreed that pathogenic microbes do not multiply in storage reservoirs, but gradually lose their vitality. The time required to effect the destruction of these bacteria is a matter of controversy. Each day's storage, however, makes for safety, and if the water is stored for a sufficient period the subsequent filtration is only required to improve the chemical and physical qualities of the water. Sand filtration under the best conditions, that is, after a scum has formed on the surface of the sand, has been found to be effective for the removal of bacteria, but as this scum eventually becomes so dense that the water cannot pass through it at the required rate, it has to be periodically cleaned off. Thus, the action of the sand filter alone is not to be relied on.

Under these conditions it is obviously desirable to store water for as long a time as possible; it is believed that danger to health by over-storage is impossible.

The water in the Thames and Lea would be utterly unfit for drinking purposes were it not for the fact that the river authorities take certain precautions against dangerous contamination. The work of the river authorities has, therefore, a most important bearing upon the London water supply. These rivers forming as they do the only possible drainage channel of their respective watersheds must necessarily receive the whole of the sewage of the population above the waterworks intakes. Everything possible is done to make local authorities and private persons purify sewage to a high chemical standard before it is discharged into the rivers, and this purification and the subsequent large dilution in the river combined with natural purification in the stream has hitherto sufficed. The problem is, however, a very serious one owing to the increase of the population discharging sewage, and to the increase of the population requiring a supply of water.

It is practically impossible to say what is the ultimate supply of water available for London as gaugings taken on the river weirs do not take proper account of the enormous quantity of water flowing down the river valleys in time of floods; neither do they take into account the subterranean flow which is probably considerable. However, some idea may be obtained from the gaugings taken at Teddington Weir on the Thames and at Fieldes Weir on the Lea below the waterworks intakes. Presumably in times of flood accurate gaugings are impossible as the weir sluices must be open and the floods may extend beyond the river banks. Disregarding these by no means unimportant facts we find that gaugings taken in the year ending March 31, 1908, show that on the average about 1,289,800,000 gallons per day flowed over Teddington Weir after the Water Board had abstracted their supply.

In this year the daily quantity abstracted from the Thames was 122,600,000 gallons or about ·0868 of the whole flow.

Similarly in the case of the river Lea in the same year the gaugings at Fieldes Weir showed that 78,800,000 gallons of water flowed over the weir on the average per day after the Board had abstracted their supply, which was on the average 45,100,000 gallons, or about ·364 of the whole flow. It will be seen that the proportion of water drawn from the river Lea is very much higher than that drawn from the river Thames. The safety of the London consumer with regard to the purity of the water supplied is guarded by the vigilance of a staff of chemists and bacteriologists who, under the control of the Board's Director of Water Examinations, are continually testing the water. In the year above quoted no less than 11,760 samples of water were examined either chemically or bacteriologically.

With regard to the future it is probable that the existing sources of supply will continue to be used for some time to come owing to the enormous works which would be required in order to obtain an adequate supply from any fresh source. It has been proposed to obtain a supply from Wales, but it is improbable that this vast undertaking will commend itself to the London ratepayer so long as the public health remains good and the supply of water is sufficient in quantity. By comparison it would be far more economical to purify all sewage entering the Thames to a bacteriological standard and to do much more than is now being done to prevent river pollution. The natural sources of supply for London water are to be found in the rivers, and it is from every point of view desirable and essential that these rivers should be kept absolutely pure. Much unnecessary pollution which is easily preventable now takes place. Works capable of purifying sewage absolutely, both chemically and bacteriologically, can be and are being constructed elsewhere; and other pollution of various kinds can be reduced to a minimum. With such remedies possible, it is, therefore, probable that the Thames and the Lea will continue to be the sources of supply for London. Further with the advance of science fresh methods of purifying water are coming into use which will be available as a further means of safety when required. H. C. H. S.

Lowcock Sewage Filter.—This method, in common with that of Waring and Ducat (*see* "Waring System," and "Ducat Filter"), depends principally upon the direct oxidation of the sewage by strong aëration. The Lowcock filter contains perforated air-pipes introduced at 15 in. or 18 in. down from the surface of the filtering material. These pipes are connected with a small blower, and, the top of the filter being sealed with a layer of sand and closely packed upper layers of gravel, the air is passed downwards and out with the effluent. In the "Waring system" the air is introduced at the bottom, and the filters are aërated upwards. The object in both cases is to increase the efficiency of the filter by artificially supplying the air necessary for the support of aërobic bacterial action. The air-pressure used is equal to a 4-in. column of water. The system was tried at Malvern in 1892 with a filter of sand and gravel, and later at Wolverhampton where sand and coke breeze was used. Lowcock filters 3 ft. 6 in. deep were also put down at Tipton in 1896, with a top layer of fine broken limestone and sand, a bottom layer of coarse coke, the intermediate portion being coke breeze.

Artificial aëration is costly, and the more recent development of improved methods of distribution and natural aëration upon percolation beds of simple and uniform construction throughout, tends to show that the complications necessarily arising from systems involving forced aëration and heating are not required for the production of a good permanent effluent. Experience also shows that for large sized works, at any rate, simplicity of construction and adherence to natural conditions are essential and greatly facilitate smooth working.

"**Made Ground.**"—A term applied to land, such as a building site, the level of which has been raised and made available by shooting or tipping surplus earth, and *débris* of various kinds, so as to fill up hollows and irregularities of surface, or, in some cases, to elevate the surface above the flood level. "House refuse" is often disposed of by tipping upon low lying marsh-land on the outskirts of towns as is done in some of the southern and eastern neighbourhoods around London. The owners of such otherwise undesirable sites reap a good income by allowing tipping of such material including builder's refuse, &c., at a charge of a few pence per load. Such "made ground" sites often ultimately become "eligible building plots" at greatly enhanced values, but the practice must be condemned upon sanitary grounds, and the model building bye-laws of the Local Government Board contain special provisions against the erection of new buildings upon insanitary sites.

Main Drainage of Towns. — (*See* "Sewerage.")

Manchester Sewage.—Experts' Report.—The sewage of Manchester originally found its way into the Irk and the Medlock, thence to the Irwell, and finally into the Mersey. The completion of the Ship Canal necessitated some method of treatment as the above-mentioned rivers became the source of supply to the Canal. Works for treatment of the sewage by chemical precipitation were completed in 1893. (*See article* "Manchester Sewage Works.") It was recognised from the first that chemical treatment would be inadequate, and originally intermittent filtration through land was contemplated. The area which would be required was, however, soon seen to be very large. Under the direction of Sir Henry Roscoe, experiments were carried out with small filters of clinker and coke-breeze on similar lines to Mr. Dibdin's experiments at Barking. Favourable results were obtained, but owing, among other reasons, to apprehensions as to the ultimate cost of artificial processes, a scheme was prepared by the City Surveyor for conveying the effluent to the upper tidal reaches of the Mersey, the discharge to take place at Randall's Sluices, a short distance below Warrington. The scheme met with strenuous

opposition from Warrington and Liverpool and other riparian authorities, and was finally rejected on a poll of the ratepayers in Manchester. The City Council therefore resolved, in June, 1898, to appoint a commission of experts to consider the whole question.

The commission consisted of Mr. Baldwin Latham, engineer; Professor P. F. Frankland, bacteriologist, and Professor W. H. Perkin, Jun., chemist. Under the direction of these gentlemen, a series of experiments, on the treatment of sewage by various methods, was begun in 1898, a report was issued in 1899, and a supplement in 1900.

In addition to continued observation of the results obtained from the experimental beds started by Sir Henry Roscoe, the following lines of investigation were pursued :—

The treatment of raw sewage by single, double, and triple contact on bacteria beds;

The treatment of settled sewage by single, double, and triple contact on bacteria beds;

The treatment of raw sewage by means of the open septic tank followed by one or more contacts on bacteria beds;

The treatment of raw sewage by means of the closed septic tank followed by one contact on bacteria beds;

The treatment of storm-water.

From these experiments, it was concluded :—

(1.) That the bacterial system is the system best adapted for the purification of the sewage of Manchester.

(2.) That the bacterial processes are best conducted in several stages, viz. :—

(i.) Settlement and screening out of the grosser solids.

(ii.) Anaërobic decomposition in the septic tank.

(iii.) Oxidation on bacteria beds.

For thoroughly satisfactory purification more than one contact is necessary for Manchester sewage; but the experiments showed that the area of secondary beds might be considerably less than the area of primary beds.

As a result of these experiments, and after consideration of methods in use in other towns, a complete scheme for the treatment of Manchester sewage by bacterial methods was proposed, and, with modifications made by the Local Government Board, was passed by the City Council in September, 1900.

G. J. F.

Manchester Sewage Works.—Davyhulme Works.—The main works for the disposal and purification of the sewage of the City of Manchester are situated at Davyhulme, (Station Urmston, Cheshire Lines Railway) about five miles from the centre of the city.

The original works, which first came into operation early in 1894, were designed for the treatment of the sewage by chemical precipitation.

The new works for bacterial treatment of the sewage were completed in 1904, so far as to permit of the whole of the flow being dealt with in tanks and primary contact beds.

It was originally intended to place the second contact beds on land at Carrington and Flixton some two miles from Davyhulme. Land, however, has been acquired in the immediate vicinity of the present works, and powers have been obtained to construct the secondary beds thereon. The effluent from these beds passes direct into the Manchester Ship Canal, without any final treatment upon land.

The land at Carrington and Flixton is retained in the possession of the Rivers Committee of the Corporation for the purpose of future extensions should they at any time become necessary.

The sewage as it enters the works passes through a system of screens and catch-pits, designed to intercept coarser floating matter and heavy detritus. The flow is either passed through open septic tanks on to the half-acre primary contact beds, or, after simple sedimentation, on to the storm-beds.

The sludge which deposits in the sedimentation tanks, or which accumulates in the course of time in the septic tanks, flows by

gravity, or is pushed by manual labour, into channels leading to two ejectors from which it is forced under air pressure into two storage tanks near the banks of the Ship Canal below Barton Locks. From these tanks it flows by gravity into the sludge steamer and is deposited at sea beyond the Mersey Bar. Occasionally a portion of the sludge is pressed and disposed of among neighbouring farmers.

There are four sedimentation tanks, two on each side of the central roadway. Each of these is 300 ft. in length, 100 ft. in width, with an average depth of 6 ft., containing a volume of 1,125,000 gallons.

There are twelve open septic tanks with a total water capacity of 15,820,250 gallons, giving approximately a time of flow through the tanks of 15 hours in fine weather.

There are 92 primary contact beds, covering in all 46 acres, each being a net half-acre in area. Their general method of construction will be clear from the following: The beds are constructed in concrete and are filled with screened clinkers to an average depth of 3 ft. 4 in. The bulk of the filtering material consists of fragments from 2 in. to ¼ in. diameter. Larger clinkers are placed over the underdrains, and as far as possible over the whole bottom of the bed.

Clinkers have been used as a filtering medium, as experiments showed them to give the best results from the point of view of purification, they could be rapidly and cheaply obtained, and after four or five years could be taken out and washed at a cheap rate, so as to eliminate the softer portions, yielding eventually, in this way, a hard resistant material, at a less cost than material of equal quality could be obtained in the first instance.

There are 27 acres of storm-beds 2 ft. 6 in. deep. The filtering medium is unscreened clinkers, well underdrained. The beds are designed to act mainly as straining filters, and the surfaces have to be scraped from time to time.

The population draining to the works is 577,230. The strict dry weather flow, based on the water-supply plus certain allowances for private wells, &c., is taken at 21,000,000 gallons per day. The works are designed according to the usual Local Government Board requirements on this basis. The average actual dry weather flow including sub-soil drainage is approximately 27,000,000 gallons, and the average total flow including storm-water for the year ending March, 1908, was 36,700,000 gallons per day.

The sewage contains a very great variety of trade-effluents, notably ammonia recovery liquors (both from the gas-works, and from private manufacturers of sulphate of ammonia), and effluents from galvanizing works and from dye-works. Owing mainly to these effluents, the composition of the sewage and the results obtained by the septic tanks and bacteria beds are not comparable with corresponding data for works dealing only with domestic sewage.

It has been found possible to obain a purification of from 70% to 75% by means of open septic tanks followed by first contact beds operated at a rate of upwards of 120 gallons per cubic yard per day. A second, contact bed worked at the rate of 150 gallons per cubic yard per day has been found capable of effecting a further purification of from 65% to 70% on the first contact effluent or a total purification of 90% with production of a final effluent which is uniformly non-putrefactive.

The total capital expenditure on purification works to March, 1908, including the cost of the original works for chemical precipitation, estimated outlay for the secondary beds now under construction, and unused land at Carrington and Flixton, amounts to £494,614 or 17*s.* per head of population served. The average annual revenue cost of treatment for the 5 years ending March, 1908, exclusive of interest and sinking fund, amounts to £19,310, or 8*d.* per head of population.

Withington Works.—These works serve a population of 60,000 situated in the districts of Withington and Levenshulme with an average daily sewage flow of 4,185,000 gallons.

The process adopted for treating the sewage is sedimentation, followed by further purification of the effluent on first and second contact

bacteria beds. There are two detritus tanks (capacity 83,400 gallons), two sedimentation tanks (capacity 781,000 gallons), ten first contact beds (2,900 superficial yards each), an equal area of second contact beds, and a total area of storm-beds of 12,452 superficial yards.

The sludge is disposed of by trenching into land, on which crops of various kinds are grown.

The sewage is purely domestic and much diluted by sub-soil water. The cost of actually treating the sewage, apart from pumping and refuse disposal charges for the year ending March, 1908, was £1 5*s*. 9*d*. per million gallons or 7·84*d*. per head of population.

Moss Side Sewage Farm.—The sewage of the suburb of Moss Side is at present treated by chemical precipitation, a portion of the effluent being further purified on land. The amount of the latter is, however, inadequate, and it is intended to divert the sewage to the main works at Davyhulme at an early date.

G. J. F.

Manholes.—(*See* "Sewerage.")

Mannesmann Pipes. — Mannesmann weldless steel spigot and faucet pipes for gas and water mains are made by the British Mannesmann Tube Co., of London Wall, E.C. The pipes are manufactured in lengths up to 35 ft. and can be bent cold on the spot if required. The advantages claimed for this class of tube include saving in jointing, labour, and materials, also in freight and transport with immunity from breakage in transit or when laid. The pipes are specially coated with the object of preventing corrosion.

Manometer.—A general term applied to instruments for indicating the intensity of fluid pressure. These are more commonly called "pressure gauges" or "vacuum gauges," according to whether the pressure to be measured is above or below that of the atmosphere. The simplest and most accurate manometer is that in which the pressure is caused to act upon a balanced column of liquid (mercury) contained in a glass tube. The displacement of the mercury increases with the pressure and thus affords an indication of its intensity. The mercurial gauge is used for scientific purposes, and as a standard for testing and calibrating ordinary gauges. The U-shaped tube containing water, employed by gas engineers and others, is upon the same principle. The gauges used for ascertaining the pressure of steam, air, water, &c., in practical work, are nearly always of the "Bourdon" or "Schäffer" type. The mechanism of the former consists of a curved metallic tube of elliptical cross section; one end of this tube is closed, the other communicates with the boiler, condenser, &c. Pressure exerted upon the interior of the tube tends to change the elliptical into a circular section and in so doing straighten the tube and cause movement of its free end. On the other hand, if the pressure inside the tube is below that of the atmosphere a contrary effect takes place. The bending action of the tube is transmitted to a pointer moving over a graduated scale. In the "Schäffer" gauge the pressure is applied to a flexible corrugated steel diaphragm. In both cases a quadrant rack and pinion are employed to amplify the range of the pointer.

E. L. B.

Markets. — **Acts of Parliament — Cattle Markets—Site—Pens and other Departments—Markets for General Merchandise—Removal of Refuse.**

Acts of Parliament, &c. — Markets and Fairs Clauses Act, 1847; Towns Improvement Clauses Act, 1847; Public Health Act, 1875; Public Health (London) Act, 1891; Public Health Act, 1908. Public bodies are empowered to provide public markets in their towns or districts by section 166 of the Public Health Act, 1875, which states:—"Where an urban authority are a local board of improvement commissioners, they shall have power, with the consent of the owners and ratepayers of their district, expressed by resolution passed in manner

provided in Schedule III. to this Act, and where an urban authority are a town council they shall have power with the consent of two-thirds of their number, to do the following things, or any of them, within their district:—

"To provide a market place, and construct a market house and other conveniences, for the purpose of holding markets;

"To provide houses and places for weighing carts;

"To make convenient approaches to such markets;

"To provide all such matters and things as may be necessary for the convenient use of such market;

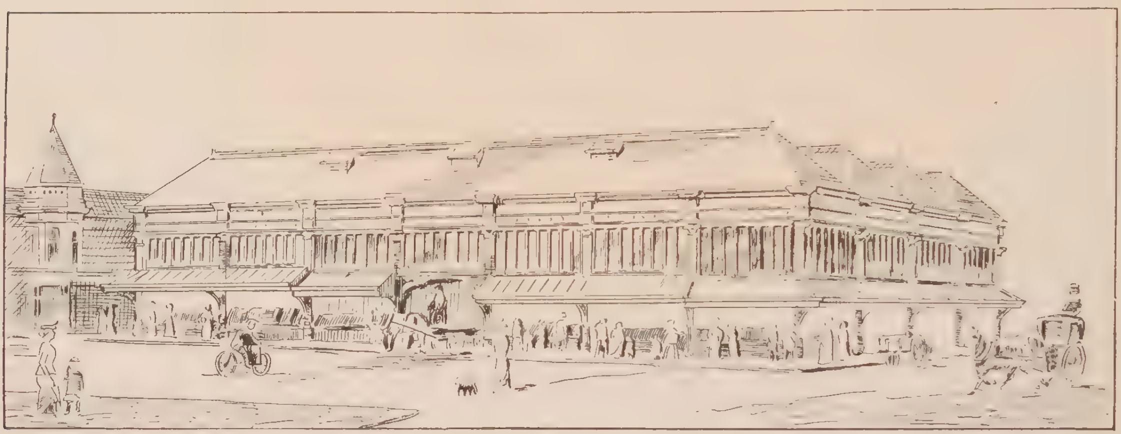
"To purchase or take on lease land, and public or private rights in markets and tolls for any of the foregoing purposes;

"To take stallages, rents, and tolls in respect of the use by any person of such market.

"But no market shall be established in pursuance of this section so as to interfere with any rights, powers, or privileges enjoyed within the district by any person without his consent." A study of the Model Bye-laws, issued by the Local Government Board will also prove very useful and instructive.

Several of our large towns have established markets both for cattle and general goods, whereas in smaller towns a cattle market has been provided and a large square in the centre of the town laid out as a market for general merchandise.

Cattle Markets: Site.—The site for a cattle market should be near the railway station sidings, so as to avoid the harmful and dangerous passage of the animals through the streets of the town. It should also be near the public abattoir (if there is one provided in the town) for exactly the same reason, and also because the length of the distance travelled by the animal makes a great difference in the weight of the meat after killing. It may be possible to provide on the site for the erection of a small disinfecting station, and in selecting the site of the cattle market this should be borne in mind. The site must be well drained, as far away as possible from the inhabited portion of the town, and in a good open quarter. It should be surrounded by a high wall and have several entrances, each of large double gates. These may be either of wrought iron or wood. Plenty of room should be allowed in the market for the easy passage of the cattle to the different sections and pens, &c., provided; and drinking troughs at each entrance and in other convenient places, several in number, should be provided. Water hydrants should be provided in large numbers to flush the paving and floors of styes and pens. The paving of the site will be a matter



Market Buildings.

requiring careful consideration, care being taken to provide materials which will have the least tendency towards slipperiness. The whole of the site inside the enclosing walls should be paved. It is usual to provide the following accommodation, but the needs vary with different localities, either more or less being found necessary:—1. Pens for large cattle. 2. Pens for stock cattle. 3. Pens for cows with calves. 4. Covered pens for calves. 5. Pens for sheep. 6. Covered styes for pigs. 7. Stables for horses. 8. Trotting enclosure for horses. 9. Sheds or show-rooms for agricultural implements, carts, wagons, &c. 10. Ditto for seeds, grain, &c. 11. Offices for auctioneers. 12. Weigh office. 13. Superintendent's office and house. 14. Rooms or office for veterinary surgeon. 15. Waiting-rooms for drovers. 16. Covered sheds for farmers' wagons, carts, &c.

This list is merely a suggestive one, as in some districts accommodation for other purposes may be found necessary. In addition to the above, ample lavatory accommodation must be provided. Before dealing with the separate sections in detail, we will consider briefly the nature of the paving for the site. The pens and lairs should be paved with (1) granite or stone setts on 6 in. of Portland cement concrete; (2) a layer of asphalte on concrete; (3) granitic paving laid, *in situ*, and diagonally scored, to allow of easy draining, and to give a firm foothold to the cattle. These will be found to lend themselves better for cleaning purposes, besides giving a foothold for calves and pigs; and the stables for horses may be paved with (1) asphalte; (2) panelled blue bricks on 6 in. of Portland cement concrete; or (3) granitic paving as above; all laid to falls and effectively drained. The trotting enclosure for horses should be paved with setts, and the sheds for agricultural implements and farmers' carts, &c., should be paved with asphalte on concrete as described above. The offices, house, and waiting-rooms will have boarded floors.

1. Pens for Large Cattle.—These will include pens for loose cattle and pens for tethered cattle. The divisions should be of iron or wooden "post and rail" fences about 5 ft. in height. Rings for tethering the cattle should be let into the paving about 4 ft. apart.

2. Pens for Stock Cattle.—These should be constructed in an exactly similar manner.

3. Pens for Cows with Calves.—These should be somewhat larger than those for cattle as above, but otherwise will be similar. Sizes, &c., are given later on.

4. Covered Pens for Calves.—These will have divisions and walls constructed of brick. The floors should be raised above the floor of the general site about 2 ft. 6 in. or 3 ft., as these animals are generally brought in carts and can be easily transferred to or from the carts if the floor is raised. The doors may be either of iron post and rail or close boarded. The walls should be about 3 ft. above the floor.

5. Pens for Sheep.—These will be constructed on similar lines to those for cattle, except that the enclosing fence will not be so high.

The paving should be raised from the front to the back of the pen in a gradual incline, to show off the sheep better.

6. Covered Styes for Pigs will be constructed on exactly similar lines to those for calves.

7. Stables for Horses, fitted up with manger, stalls, &c., and hay loft, harness room, and other antechambers.

8. Trotting Enclosure for Horses.—A large open space with light iron post and rail fence.

The other departments are of the usual type and need not be described here in detail. With regard to the sizes of pens, &c., for cattle and other animals, the Model Bye-laws issued by the Local Government Board in 1877 (which upon consultation will prove very useful), suggest the following:—

For every horse . . . 8 ft. by 2 ft.
,, ,, ox or cow . . 8 ,, ,, 2 ,,
,, ,, mule or ass . 5 ,, ,, 15 ins.
,, ,, calf . . . . 5 ,, ,, 15 ,,
,, ,, sheep, goat, or pig (of medium size) 4 ft. (superficial).

If these dimensions are worked to, and inquiries made into the number of cattle likely to be brought, the sizes of the pens, &c., will be easily found. Large boards with the names of the various sections painted on should be posted up over those sections to enable drovers to easily find the pens, &c., for their different cattle and animals.

Markets for General Merchandise.—These are generally buildings of an imposing character, and are treated as buildings worthy of architectural beauty. They generally include some, or all, of the following sections:—

Dead meat market. Fish, game and poultry market. Fruit, flowers and vegetables market. Hardware, ironmongery, and fancy goods market. Dairy produce market. Grocery and provisions market. Drapery and clothing market. Public conveniences. Offices, &c., for market superintendent.

The buildings should be lofty, and preferably all sections on one floor. The floors should be level with the adjacent streets, and paved with impervious paving, *e.g.*, asphalte or granite setts, so as to be easily washed down. Gangways should be constructed in the different sections for vehicular traffic, the portions between being raised about 4 in. above and edged with granite kerb. Drainage should be very carefully considered, and ventilation and light must be plentiful. Standposts must be placed in convenient positions, and should be plentiful in the meat, fish, game and poultry sections.

Removal of Refuse.—Large manure-pits must be provided for the cattle market to receive all manure from the pens and styes. The general refuse, dirt, &c., may be swept up, and carted away immediately to the refuse depôt. In the case of the general market, separate bins should be provided for refuse to each shop and stall, the contents being removed daily, especially in case of the meat, fish, game and poultry, and vegetable sections.

R. H. B.

Mather and Platt's Filters.—(*See* "Mechanical Filtration.")

Mechanical Filtration (of Water Supplies).—The mechanical filtration of water for purposes of public supply has been practised for many years past in the United States of America, upon the Continent of Europe, and many other places, but it is only of more recent years that this method of purification has attained any considerable foothold in this country. There is no doubt as to the efficiency of the more generally adopted slow sand-filtration process as extensively employed for large supplies where it is carried out under careful supervision and control, but the capital cost of such filters is heavy per million gallons filtered, and the ground space occupied by the beds is large compared with the more intensive and compact system of mechanical purification. The ordinary gravitation sand filter for efficient filtration does not, as a rule, pass water at a greater rate than from 18 to 20 gallons per square yard of surface per hour, or say at about 450 gallons per square yard per day of twenty-four hours, whereas the mechanical filter is capable of efficiently treating some 160 gallons per square foot per hour, the actual speed of filtration in any given case depending largely upon the nature of the crude supply and the degree of purification to be obtained. There are various types of mechanical filters in use, for example (1) those depending on straining action only; (2) those combining coagulation and subsidence with straining worked either as gravity filters or under pressure; and (3) those utilising the oxidising effect of the imprisoned air by pumping in water under pressure and then taking out suspended impurities by mechanical straining.

In the United States of America, where river and lake waters are largely used, there are many installations of the Jewell system and other mechanical processes, in most of which a coagulant is added to the water before it passes to the filter. The Alexandria Water Co.

(Egypt), has adopted the system of the Jewell Export Filter Co., of New York, for treating 8,000,000 gallons of water daily from the Mahmondieh Canal, which is in direct communication with the Nile. In England the Jewell filters are in use at York and Wolverhampton. Some of the leading features of the filter are: the negative head, the screen system, the uniform rate of flow and automatic control of the water level over the filter bed, and the rate of filtration, a weir around the filter tank for the removal of the dirty wash water, and the arrangement of valves by which the working of the filters is controlled. Previous to passing through the filters waters are subjected to coagulation and sedimentation. Iron waters are treated by the addition of lime followed by aëration and then rapid filtration. The filters are variously constructed in reinforced concrete, masonry, steel or wood.

Other systems in use in the United States, principally for the filtering of turbid river or lake water are the "Hyatt," the "Loomis," the "Bowden," and the "Duplex."

In England, three of the best known types of mechanical filters are the Candy oxidising pressure filters, Mather and Platt's gravity and pressure filters, and Bell's filters.

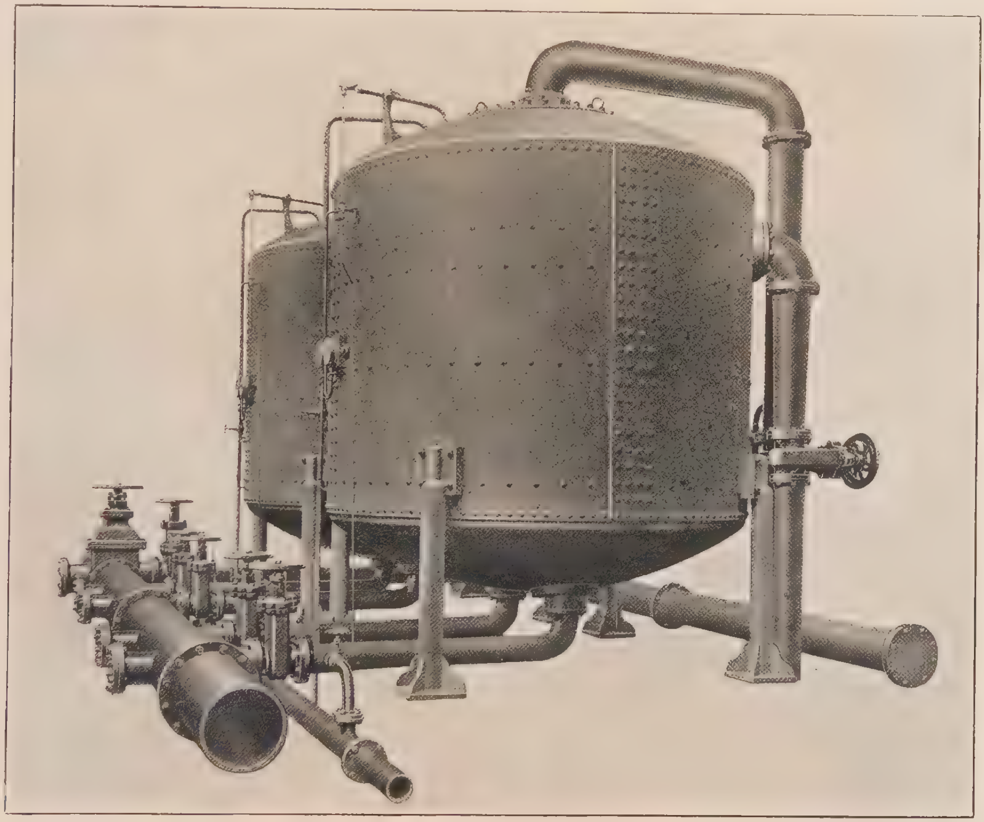


Fig. 1.—Candy Filters, Cape Town Municipality.

The Candy System (Figs. 1 and 2).—These filters consist of steel cylinders of the form shown in the illustration and into the upper part of which water is pumped under pressure and filtered downwards through about 5 ft. of filtering materials consisting of layers of pure silica sandwiched in between which is a layer of about 2 ft. in thickness of "oxidium" (*see* "Oxidium"). The filters are of special

service in the removal of iron from waters used for public supply, whether in solution or suspension; for the removal of peat or other discoloration, and also for the removal of organic matters and bacteria. The principle upon which the system works is as follows:—Water is either pumped through the filter, or outlet leading to clear water storage reservoir. A special feature of the system is that when water contains iron in solution, the iron is instantaneously oxidised and thrown into suspension, so that it is readily removed by passing through the bed of filtering materials. The pressure under which the filters work

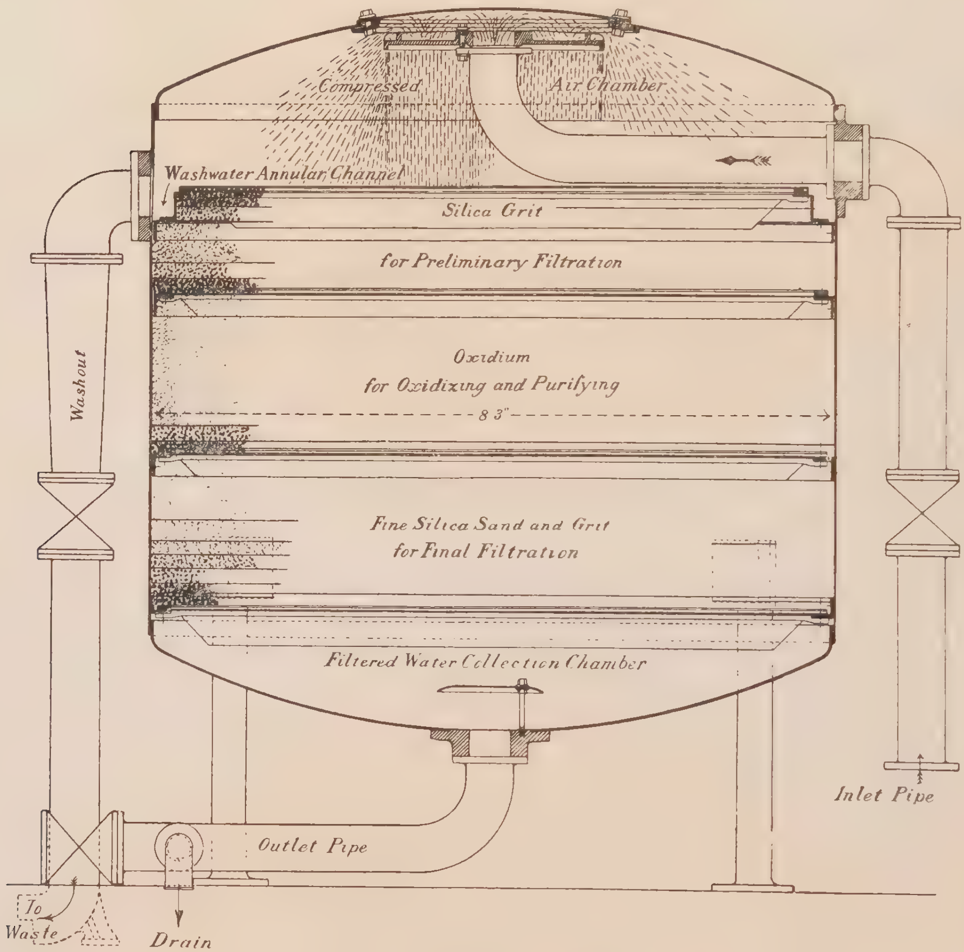


FIG. 2.—Candy Filter. Section.

passed through by the head from a gravitation main, which upon entering compresses the air contained within the filter to such pressure as may be arranged. This materially hastens the oxidation of iron or organic impurities contained in the water, which subsequently passes downward, through the filtering materials above mentioned, to the is commonly from 5 lbs. to about 25 lbs. to the square inch, but this is a matter which must be adjusted to suit the particular conditions and water under treatment. The process of oxidation is hastened and intensified if atmospheric air is pumped into the filters by a small auxiliary air pump, as is done at an installation of these filters at the Tunbridge

Wells Corporation Waterworks. The system is used for the public supplies of the corporations of Hastings, Cardiff, Newport (Mon.), Merthyr Tydvil, Harrogate, Tunbridge Wells, by municipal authorities in South Africa, and by a number of water companies. The results of chemical and bacteriological analyses show the system to give an effluent of a high degree of purity. A filter 8 ft. 3 in. diameter is capable of dealing with from 8,000 to 9,000 gallons per hour, or at the rate of 160 gallons per square foot per hour. The filter is rapidly cleansed by simply reversing the flow of water through it by means of a connection to the filtered water or high pressure mains. The quantity of "wash-water" required varies from ·3 to ·7 °/o of the total filtered, according to the nature of the crude supply dealt with.

The relative cost of mechanical *versus* sand filtration depends very largely upon local conditions, but, under ordinary average conditions, the capital cost per 1,000 gallons effective working capacity per day in the case of sand filters may be taken at about £15, allowing for one-fourth of the total area being out of use for cleansing, whilst in the case of mechanical filters of the above type the capital cost per 1,000 gallons effective working capacity per day amounts to between £3 and £4. The working expenses in connection with the mechanical filters is found to be about 1*s*. per million gallons filtered, as compared with from 3*s*. to 5*s*. per million gallons with sand filtration on large works. In the case of small works sand filtration would compare much less favourably.

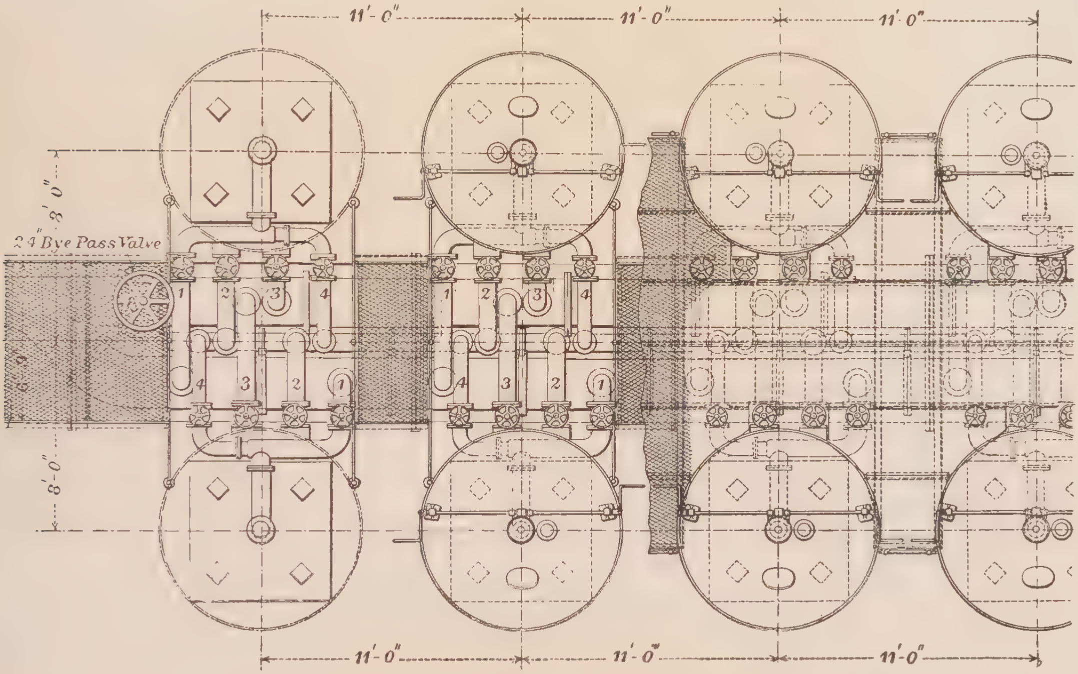


Fig. 3.—Mather and Platt's Pressure Filters. Plan.

The Mather and Platt Pressure Filters (see Figs. 3 and 4).—These consist of closed cylindrical tanks, with sloping sides and domed top and bottom, supported on four cast-iron legs. The larger-sized tanks are made of riveted steel plates, and the smaller sizes of cast iron. Inside, at the upper part of the cylinder, is fitted an annular channel through which the unfiltered water enters from the inlet valve, over-flowing the edge on to the bed of filtering material, and passing down through it to the collecting chamber at the

bottom. The filtering material consists of quartz crystals in graded layers, with the finest at the top. From the illustration (Fig. 4) it will be seen that the bed rests on a dished iron plate which separates the filtering and collecting chambers. A considerable number of brass nozzles are screwed from the underside into the dished iron plate, ready access being obtained by means of a door fitted in the side of the collecting chamber, so that they may be replaced without disturbing the quartz bed. The object of these nozzles is to secure the effective use of all parts of the filtering bed as well as the uniform distribution of the water used in washing the filter. The annular channel, above referred to, serves to spread the unfiltered water over the bed and to carry off the dirty water when the filter is cleansed. For cleansing the filter the direction of flow is reversed; the unfiltered water inlet valve and the filtered water outlet valve are closed, and the wash-out inlet valve and wash-out discharge valve opened. The impurities filtered from the water collect, mostly, in the top of the bed, and in order to facilitate their removal during the wash-out a rake, which can be rotated by hand, is fitted inside the cylinder, with the object of breaking up the surface of the bed during the cleansing operation. When the water from the wash-out discharge valve is seen to be clean, this valve and the wash-out inlet valve are closed and the water again admitted through the unfiltered water inlet valve. This water, however, is not allowed to pass to the mains, the filtered water outlet valve being still kept shut, but instead, the re-wash valve at the bottom of the filter is opened for a few seconds to allow the first discharge to run to waste, so as to clean the nozzles and collecting chamber of any dirt which may have entered with the wash-out water, and to settle the upper layers of the quartz bed into a properly compact condition.

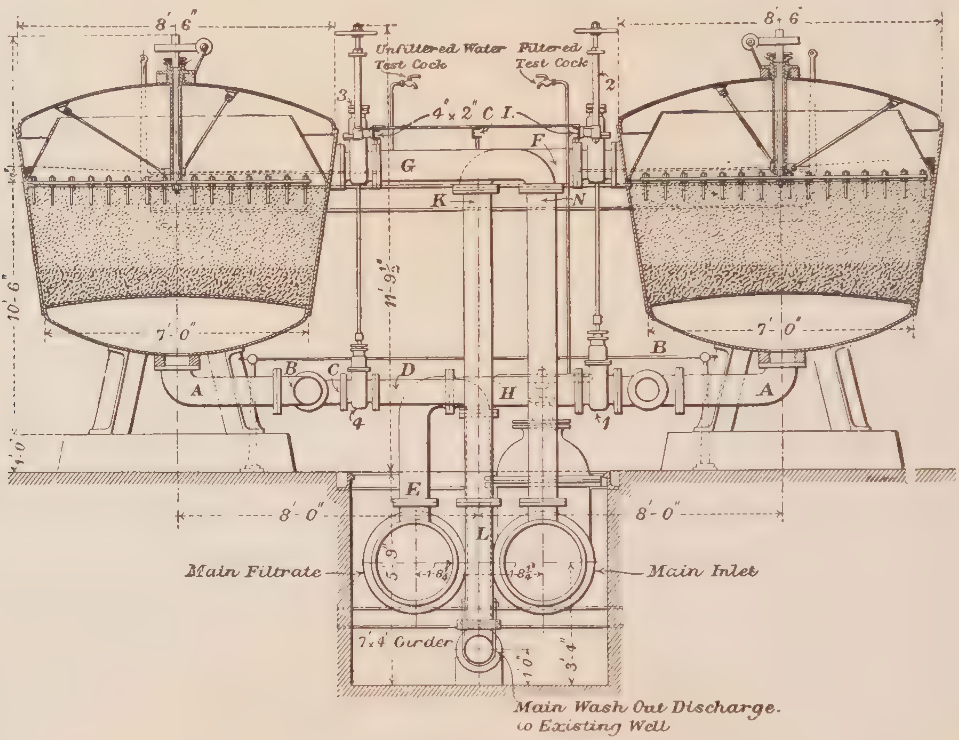


FIG. 4.—Mather and Platt's Pressure Filters. Section.

The filtration plant, illustrated in Figs. 3 and

4 erected in 1907 by the Bolton Corporation at Belmont Road reservoirs, is contained in a brick building 80 ft. by 40 ft., and consists of ten filters of the above described pressure type, each 8 ft. in diameter. The plant is capable of dealing with 3,000,000 gallons per day under a working pressure of 200 ft. head, equivalent to 87 lbs. per square inch.[1] These filters are arranged in two rows of five each, the rows being spaced 16 ft. apart from centre to centre, and the filters placed at 11-ft. centres. Between the two rows of filters is arranged a central gallery, supported by iron beams carried on brackets attached to the outside of the filter cases; from this gallery the whole of the valves, agitating rakes, and other gear can be worked. The water is delivered to the filters through a 24-in. main, the quantity being measured and recorded by a Venturi meter placed in one angle of the filter house. This main extends in a trench the whole length of the house, and alongside it is a second 24-in. main for the filtered water, while below is an 8-in. pipe to carry off the wash-out water to a suitable outlet.

Bell's Filters.—A typical installation of this type of pressure filter has been put down at Dunoon, where a battery of twelve filters of 8 ft. diameter each are in use for treating discoloured peaty water from reservoirs on the bed of the Balgie Burn. Each filter will pass 10,000 gallons per hour, but is rated at a minimum output of 6,500 gallons per hour, or 78,000 gallons per hour for the twelve. At Dunoon the water is treated chemically before it passes to the filters. This treatment consists in adding to the water a saturated solution of lime and a solution of alum, varying in strength according to the colour of the water to be treated. The object of the treatment is to remove the peaty matter to which the discoloration is due. The internal arrangements and mode of washing these filters are described by Mr. James Andrew, the burgh surveyor of Dunoon, as follows:—"Each filter contains approximately 7 tons of fine Leighton Buzzard crushed quartz, on the top of which the raw water descends. There are 144 strainers at the bottom, conical in shape, with detachable perforated lids having countersunk holes. The narrow ends of the strainers are fixed to 1-in. pipes, which in turn are connected to a series of 3-in. pipes, the 3-in. pipes again connecting to the filter outlet. The strainers are filled with pea gravel, and the space between the bottom of the shell and the bottom of the strainer lids is filled with concrete. This arrangement at the bottom induces the whole of the filtering medium to be continuously brought into action, the inclination of the water to descend vertically being no greater at one point than another. The period of time during which the filters run without washing depends on the condition of the water, and intimation that it is necessary to wash is conveyed by the gauge. When the water is at its best washing is necessary only once in three days; when it is at its worst it becomes necessary to wash twice in 24 hours." Mr. Andrew also states that "the alumino-ferric used is obtained from Messrs. Peter Spence & Son, of Manchester, and costs £3 per ton delivered at Dunoon Pier. The chemical treatment costs on an average 2*s*. 4*d*. per million gallons of water filtered. The cost of treatment for labour and chemicals is 7*s*. 4*d*. per million gallons. The total cost, including interest and repayment of capital, is about 20*s*. per million gallons."

[1] The installation worked at this rate for some time removing nearly 100% of suspended matter, but as it was deemed necessary to remove the peaty stain and bacteria, sulphate of alumina was added, and the quantity of water treated daily was reduced by one half.

Metals: Alloys are not merely mixtures of different metals, they partake more of the character of solutions; were they simple mixtures the properties of the compound would be the mean of the constituents, whereas in many cases new properties are developed. The structure of alloys has been most satisfactorily explained by considering that different metals are soluble in each other in different proportions under

different states of concentration and at different temperatures. The structure of steel has been very thoroughly worked out, and it has been shown that it consists of a solid solution of carbon in pure iron, while that of cast-iron is explained by the fact that the amount of carbon soluble in the molten iron is so great that a portion separates out, as graphite, on cooling. White cast-iron is that which has been cooled suddenly, so that the carbon remains in chemical combination, not having had time to separate out, while the same iron will become grey cast-iron if cooled slowly, a small portion only of the carbon remaining in chemical combination and the remainder being present in mechanical mixture. The most notable alloys after iron are those of copper with tin and zinc. Bronze is a mixture of about 10 parts copper and 1 tin, brass is a mixture of about 2 copper and 1 zinc, gun-metal is a mixture of about 16 copper, 2 tin, 1 zinc. Variations in the proportion of the constituent metals produce considerable variation in the properties. Some of the principal mixtures are:—

BRONZE ALLOYS.

Name.	Copper.	Tin.	Zinc.	Lead.
Pumps (very tough)	32	3	1	—
Pump plungers	14	1	1	—
Engine bearings	112	13	$\frac{1}{4}$	—
Heavy bearings	32	5	1	—
Hydraulic valve faces	4	1	—	—
Valves and mountings	90	10	$2\frac{1}{2}$	—

BRASS ALLOYS.

Name.	Copper.	Zinc.	Tin.	Lead.
Tough for engine work	100	15	15	—
For turning and fitting	3	—	1	$\frac{1}{12}$
Stop cocks and valves	73	7	8	12

SOLDERS.

Spelter for brazing (hard)	3	—	2	—
,, ,, (soft)	1	—	1	—
Tinmen's fine solder	—	3	—	1
,, coarse solder	—	1	—	1
Plumbers' fine ,,	—	1	—	3
,, coarse ,,	—	1	—	3

Alloys are used for various purposes with two chief objects in view, firstly to reduce friction, as in the case of bearings for machinery, and secondly to avoid corrosion, as in pump rams, cocks, bolts, screws, &c. The simple metals used in forming alloys are non-corrodible, but some of them are too expensive when used alone, as copper or tin, and others are wanting in toughness, as zinc or lead. A judicious mixture will produce the properties most desired. Copper is the principal ingredient in nearly all alloys, its characteristics being modified by admixture as follows. Tin increases the hardness, and whitens the colour through various shades of red, yellow, and grey. Zinc in small quantity increases fusibility without reducing the hardness, in greater quantity it increases the malleability when cold, but entirely prevents forging when hot; 1 to 2 % of zinc enables sounder castings to be made. Lead increases the ductility of brass, and makes the alloy more suitable for turning, filing, &c.; in large quantity it causes brittleness. Phosphorus increases the fluidity and tenacity, reduces the effect of the atmosphere, and allows of tempering; it also produces sounder castings. For brass exposed to sea-water, tin is distinctly preservative, while lead and iron are both injurious, rendering the alloy more readily corrodible; the percentage of the two latter metals should therefore be kept as low as possible in all brass intended for purposes where contact with sea-water is inevitable.

H. A.

Meteorology.—Meteorology is that branch of science which deals with climate and weather. The term "Climate" may be defined as the average condition of meteorological phenomena at a given place, while under the term "Weather" may be included the condition of the atmosphere at any moment with regard to wind, temperature, cloud, moisture, and precipitation.

INSTRUMENTS.—At a Climatological station the essential instruments for making meteorological observations are only a Stevenson Thermometer Screen, containing dry-bulb, wet-bulb, maximum and minimum thermometers, and a Snowdon rain-gauge. Some stations have in addition a sunshine recorder, a grass minimum thermometer, and one or more earth thermometers, and many stations have also a barometer. Most of these instru-

ments are described in other parts of this volume.

TEMPERATURE.—The "mean temperature" is usually determined by adding together the readings of the maximum and minimum thermometers and dividing the sum by 2. The "range of temperature" is the difference between the readings of the two thermometers. The range is greatest at inland places owing to radiation, and least on the coast, where the sea has a moderating effect on the temperature. On July 22, 1868, a maximum temperature of 100·5° F. was registered at Tonbridge and on December 4, 1879, a minimum, temperature of — 23° F. was registered at Blackadder, Berwickshire. The mean temperature and also the highest and lowest temperatures, as recorded at the Royal Observatory, Greenwich, since 1841, are as follows:—

Months.	Mean Temperature.	Extremes.			
		Highest.	Year.	Lowest.	Year.
	Deg.	Deg.		Deg.	
January	38·6 F.	57·0 F.	1843	4·0 F.	1841
February	39·5	63·9	1899	6·9	1895
March	41·9	71·5	1848	13·1	1890
April	47·3	81·5	1865	23·0	1847
May	53·1	87·5	1880	28·1	1877
June	59·4	94·5	1858	35·6	1869
July	62·7	97·1	1881	38·7	1863
August	61·6	95·1	1893	38·1	1864
September	57·2	93·5	1906	30·6	1885
October	50·0	81·0	1859	24·7	1890
November	43·5	67·3	1847	18·3	1890
December	39·9	62·4	1848	8·0	1860
Year ..	49·6	97·1	1881	4·0	1841

The isothermal maps of the British Isles show that in winter the highest mean temperature is on the south-west to west coasts, and that it decreases towards the north or north-east; the coldest parts, however, are the eastern inland districts, while in summer the inland districts are the warmest. The influence of the warm water of the Atlantic is shown in a very marked manner by its effects on the west coasts.

MOISTURE.—The quantity of water-vapour or moisture which the air can contain is dependent on the temperature. The air at a temperature of 32° F. can contain 2·13 grains of water-vapour; at 52° F. it can contain 4·39 grains; at 72° F. it can contain 8·27 grains; and at 92° F. it can contain 15·74 grains. Thus, the higher the temperature of the air, the greater is its capacity for moisture. When the full capacity of the air for vapour has been reached, the air is said to be "saturated." The instruments used for measuring the amount of moisture present in the air are the dry-bulb and wet-bulb thermometers (*see* "THERMOMETERS"). If there is considerable difference between the readings of the two thermometers it indicates that the air is very dry; but if the readings are almost alike, it shows that the air is nearly saturated with moisture.

By means of Glaisher's "Hygrometrical Tables" the dew point, the elastic force of aqueous vapour, the vapour in a cubic foot of air, the relative humidity, and the weight of a cubic foot of air, can be worked out from the readings of these two thermometers.

CLOUD.—When the air is cooled below the dew-point, or point of saturation, the moisture becomes visible in the form of cloud or fog. Much information on the conditions prevailing in the upper air may be obtained from observations of clouds. The nomenclature of the different modifications and forms of cloud, as adopted by the International Meteorological Committee is as follows:—

Name.	Approximate Altitude.
Cirrus (Mare's Tail) ..	27,000 to 50,000 ft.
Cirro-Stratus	29,000 (average) ,,
Cirro-Cumulus (Mackerel Sky)	10,000 to 23,000 ,,
Alto-Stratus	10,000 to 23,000 ,,
Strato-Cumulus	6,500 (about) ,,
Nimbus (Rain Cloud)	3,000 to 6,500 ,,
Cumulus (Woolpack Cloud) .	4,500 to 6,000 ,,
Cumulo - Nimbus (Thunder Cloud)..	4,500 to 24,000 ,,
Stratus	0 to 3,500 ,,

Some idea of the kind of weather that is likely to follow may be formed by noticing the type of cloud, and also its direction and rate

of motion. It is customary to observe the proportion of sky covered with cloud. This is done by estimation, the scale adopted being 0 to 10, 0 indicating a cloudless sky, and 10 a sky which is completely covered with cloud or overcast.

Rain.—Rain is produced by the cooling of the air; and in nearly all cases this cooling is produced by the expansion of the air in ascending from lower to higher levels in the atmosphere. The rain is collected in a rain-gauge, and the water measured off in a graduated glass jar in hundredths of an inch (*see* "Rain-gauge"). As the prevailing wind in this country is from the South-west, the air comes from the Atlantic charged with a considerable amount of moisture, and in striking the land in the western districts it has to rise until it reaches the highest ground. In doing so it is cooled in temperature, and so its capacity for moisture is greatly reduced, and consequently it has to part with some of its moisure. On descending on the eastern side the air becomes warmer, and having parted with a considerable amount of its moisture, it is much drier. These features are brought out very distinctly on reference to a Rainfall Map of the British Isles. It is at once seen that the western parts of the country, and especially the hilly districts, are much wetter than the eastern parts. At Seathwaite, in Borrowdale, Cumberland, the average yearly rainfall is about 135 in.; while at the Stye Head, a mile from Seathwaite, the annual rainfall is about 170 in. The driest district is over the eastern counties, where the average is only a little over 20 in. According to Dr. H. R. Mill, the director of the British Rainfall Organisation, the average rainfall over the whole surface of the British Isles is about 39½ in.; over England it is about 32 in., over Wales 49 in., over Scotland 47 in., and over Ireland 42·6 in.

With regard to the limits of fluctuations in the total rainfall, the late Mr. G. J. Symons, F.R.S., arrived at the following results:—(1.) The wettest year will have a rainfall nearly half as much again as the mean; (2.) the driest year will have one-third less than the mean; (3.) the driest two consecutive years will each have one quarter less than the mean; and (4.) the driest three consecutive years will each have one-fifth less than the mean. The spring months are the driest, and October is the wettest month. The rainfall, however, is very variable from month to month; some months may have 6 in. or more, while others may have only a few hundredths of an inch, and so at some times there may be floods, and at other times droughts. When the temperature is below the freezing point, the precipitation usually takes the form of snow (*see* "Snow"). Occasionally, especially in thunderstorms, the precipitation takes the form of hail, which is frozen rain. Ordinary hailstones are small, but at times they may be very large. Instances are on record in which hailstones as large as an orange have fallen in this country.

Thunderstorms.—Thunderstorms are small atmospheric disturbances, accompanied with a considerable amount of electrical energy, which manifests itself in the form of lightning. A lightning flash may assume various forms; sometimes it is a sinuous wavy line, at others it has a number of branches, and occasionally it appears to dart all over the sky. Lightning is liable to strike exposed objects; so it is desirable that houses and buildings should be provided with efficient lightning-conductors. Sheet lightning is the reflection of lightning taking place during a thunderstorm at a considerable distance away. Instances are on record of lightning being so seen for a distance of over a hundred miles.

Thunderstorms are usually accompanied by heavy showers of rain, and sometimes hail, as well as by a squall of wind.

Sunshine.—The best instrument for recording the duration of sunshine is the Campbell-Stokes Sunshine Recorder. This consists of a solid glass ball, 4 in. in diameter, supported on a pedestal in a metal zodiacal frame. A card is placed in the focus of the ball, and on this the sun burns its own record. The greatest amount of sunshine during the year is recorded along the south coast, and the

least at inland places, especially in the neighbourhood of manufacturing districts, where the large quantities of smoke sent into the air obstruct the sun's rays.

Atmospheric Pressure.—The changes in the weight of the atmosphere are measured by the barometer (*see* "Barometer"). The barometric pressure has a variation from hour to hour during the day which is most marked in the tropics, but is slight in the British Isles. This variation consists of a double minimum and maximum, viz., the first minimum occurs about 4 or 5 a.m., and the first maximum about 10 a.m. The second and more pronounced minimum takes place at 3 or 4 p.m., and the second maximum about 10 or 11 p.m. The average height of the barometer at sea-level in London is 29·955 in. The highest recorded reading in the British Isles was 31·10 in. at Aberdeen, on January 31, 1902, and the lowest 27·332 in. at Ochtertyre, near Crieff, on January 26, 1884.

The distribution of barometric pressure is readily seen from isobaric charts. These are prepared by plotting on a map the barometer readings reduced to sea-level, and drawing lines through those places which have the same value. These lines, which are called "isobars," will then represent equal barometric pressure. It will at once be seen where the pressure is highest or lowest. The areas of high pressures are called "anticyclones," and the areas of low pressure are called "cyclones." If on these maps the direction of the wind be also plotted by means of arrows, it will be noticed that the arrows fly nearly parallel with the isobars; round the areas of high pressure they move in the direction of the hands of a watch, but round the areas of low pressure they circulate in the direction opposite to that of the hands of a watch. This applies to the Northern Hemisphere. In the Southern Hemisphere the directions are reversed owing to the rotation of the Earth.

Wind.—The direction and force of the wind are determined by the distribution of barometric pressure. As the pressure for the British Isles is usually lowest in the north or north-west, and highest in the south or south-east, the prevailing direction of the wind is consequently from the south-west. This is brought out very clearly by the following figures, which show the average number of days in the year on which the wind blows from the different points of the compass at the Greenwich Observatory:—

N.	40 days.	S.E.	22 days.	W.	46 days.
N.E.	45 ,,	S.	35 ,,	N.W.	22 ,,
E.	27 ,,	S.W.	106 ,,	Calm	22 ,,

For particulars as to observing the force of the wind *see* "Anemometer" and "Wind-Force."

Weather.—If the observations made at various places at the same hour are plotted on maps, they give a very good idea of the distribution of actual weather over a country or a continent. These maps are called synoptic weather-maps. The Meteorological Office compiles daily such maps for the British Isles and North-west Europe, for 7 a.m. and 6 p.m., and upon these it prepares forecasts of the probable weather for a period of 24 hours in advance. Storm warnings are also sent to coast stations to give fishermen and others indications of the approach of storms.

Upper Atmosphere.—During the last few years efforts have been made to obtain information as to the meteorological conditions prevailing in the upper atmosphere by means of kites. The Hargrave box-kite is used for this purpose, and the object of sending it up is to carry a meteorograph for recording the pressure, temperature, and humidity of the free air. Pilot balloons are sent up for determining the drift of the upper currents. On specified occasions a "ballon-sonde," carrying a very light meteorograph, is also sent up, and such balloons sometimes attain an altitude of as much as 14 miles above the earth's surface. The interesting point brought out from the records obtained during the ascents of these balloons, is that the temperature of the air decreases pretty uniformly up to about 6 or 7 miles above the earth, but beyond that height there is little or practically no

change, and in fact there is often an increase in temperature. W. M.

Meters, Water.—(*See* "WATER METERS.")

Metric System.—For more than 200 years attempts have been made to secure a system of weights and measures which should conform to the decimal system of notation in use in arithmetic all over the world, and should unify the various standards of length, weight, area, &c., by building them up from one single unit. The honour of proposing that the earth itself should provide this unit belongs to the Abbé Mouton, who published the proposition in 1670. It was realised during the first French Revolution mainly because the prevailing idea in France at the time was to start afresh with as clean a slate as possible. This reaction found expression in the short-lived alteration of the calendar beginning again with the year One, and renaming and changing the primary subdivisions of the time occupied by the earth in one traverse of its orbit. What is of more importance is that the new measurements were all to be decimals, thus conforming to the ordinary radix of notation used throughout the civilised world, so that the so-called "compound" operations so puzzling to most people and so wasteful of our earlier years should no longer be necessary. As early in the Revolutionary period as 1790 it was proposed to realise Mouton's idea by measuring an arc of 10° on the meridian of Paris, say, 10 or 11 miles, to calculate therefrom the quadrant of that meridian, *i.e.*, as much of it as is included between the equator and the North Pole, and to employ an aliquot part of that distance as a unit of length, and not only that, but as a unit for all measurements. This scheme was carried into execution in 1895. The arc was measured by the usual surveying methods. In other words, a base line was actually measured, of course with rules made according to the old French methods, and triangulations were then made from the base, and the length of the arc was calculated therefrom. Fresh calculations gave the quadrant, one ten-millionth part of the result thus obtained was taken as the new standard, and a rod was made of that length as accurately as the workmanship of the period would permit. This is the metre. One unfortunate misconception must here be noticed briefly. Wonderful as it may seem now, the *savants* to whom we owe the inestimable benefits of the metric system were under the delusion that they had arrived at an indestructible standard, and one not liable to be lost by any accident which might happen to the standard rod or to replicas of it. "The earth is our standard," said they, forgetting that if a thousand remeasurements of the arc were made they would all be different, and hence the unit derived from them. This now forgotten mistake detracts in no way from the supreme advantages of the metric system. All measurement depends on arbitrary standards, and the standard metre in Paris is just as arbitrary and unreproducible as the standard yard built into the wall at Westminster, or the measures on the north side of Trafalgar Square. There is no such thing as "absolute measurement." The advantages of the metric system may here be briefly recapitulated:—1. It is a decimal system, conforming therefore to all arithmetic operations by decimals, and hence workable in arithmetic without any compound rules. 2. It substitutes one standard (arbitrary although it is and must be) for different standards; one for weight, one for area, &c., &c. 3. It provides a means for unifying measures geographically. 4. It refers to all measures except the measures of time. Decimal time has been often suggested, but no scheme has been considered practicable.

The metric unit is the metre. This, primarily a unit of length, supplies all the other units:—

Unit of length:	metre.
,, weight:	gramme: the weight of a cubic centimetre of water at 4° C.
,, area:	arc: ten metres square.
,, volume:	cubic centimetres, decimetres, &c.
,, coinage:	franc, five grammes of solid silver.

Before giving a table of equivalents between the metric and the British systems one more point calls for notice, and here we have yet another advantage of the metric system. Aliquot parts and multiples of a British standard are called by names which have no reference whatever to the name of the larger measure. It is not obvious on the face of it that a foot has a definite relation to a yard, or a gallon to a cubic inch. In the metric system it is managed more rationally. Remembering that it is a purely decimal system, it is easy to see the principle governing the nomenclature. Aliquot parts are denoted by prefixing Roman numerals to the name of the standard, while a similar use of Greek numerals denotes multiples, thus :—

1 milligramme	= $\frac{1}{1000}$ gramme.
1 kilogramme	= 1,000 grammes.
1 hectare	= 100 acres.
1 centimetre	= $\frac{1}{100}$ metre.

The Greek prefix *deka* is little used, on account of its resemblance to the corresponding Latin word and the consequent danger of confusion.

Comparison of English and Metric Measures.

(Also see note at end.)

Weight.—*English to Metric.*

1 lb. av.	= 0·454 kilogramme.
1 oz. „	= 28·34 grammes.

Metric to English.

1 kilogramme	= 2·2046 lbs. av.
1 gramme	= 15·432 grains.

Length.—*English to Metric.*

1 foot	= 0·3408 metre.
1 inch	= 25·4 millimetres.
1 mile	= 1609·3 metres.

Metric to English.

1 kilometre	= 0·621 mile.
1 metre	= 39·37 in.
	= 3·281 ft.

Area.—*English to Metric.*

1 square mile	= 2·59 sq. km.
1 acre	= 4046·84 sq. metres.
1 square foot	= 0·0929 sq. metres.

Metric to English.

1 square km.	= 0·386 sq. mile.
1 hectare	= 2·47 acres.
1 square metre	= 10·764 sq. ft.
	= 1·196 sq. yds.
	= 1,560 sq. in.
1,000 sq. cm.	= 155 sq. in.

Volume.—*English to Metric.*

1 cubic yard	= 0·7645 cubic metre.
1 cubic inch	= 16·39 cubic cm.
1 gallon	= 4·54 litres.
1 cubic foot	= 28·32 litres.

Metric to English.

1 litre	= 1·76 pints.
1 cubic metre	= 35·31 cu. ft.
1 cubic cm.	= 0·061 cu. in.

It is not difficult to commit the following table to memory, as—

22 lbs.	= 10 kilos.
22 yards	= 20 metres.
22 gallons	= 100 litres.
220 gallons	= 1 cubic metre.

It must be remembered that these conversions are only approximately correct, although accurate enough for all practical purposes. The number of inches in a metre is expressed by a figure which runs to many places of decimals.

Micro-organisms in Sewage.—The decomposition of all organic matter, either of animal or vegetable origin, is due to the action of bacteria, and as sewage consists of such matters dissolved and suspended in water, it swarms with these micro-organisms, and whether it is allowed to putrefy and produce volatile bodies with a most offensive odour, or is so treated as to render it clear and odourless and incapable of undergoing putrefaction, these changes are due to the action of bacteria. Crude fresh sewage rarely contains less than one million bacteria per c.c., and generally contains several millions. These may be divided into two classes, the aërobic and anaërobic; the former growing freely only in the presence of an abundance of air, and the latter only thriving where air is excluded. The essential constituent of the atmosphere which accelerates or retards the growth of these bacteria is the oxygen; and as the real purifying organisms are aërobic, the necessity for a free supply of air during certain processes of sewage purification is rendered evident. Whilst in the sewers the aërobic bacteria have commenced the work of decomposition, and the urea found in urine and the

more readily decomposible nitrogenous matter found in excretal matter have been broken down with the production of much carbonic acid and ammonia. The *Micrococcus urea* is probably the most important organism producing this change. If now the sewage is confined in a closed tank, or the access of air is in any way prevented, the anaërobic bacteria become active, and acting upon the more insoluble portions decompose them with the production of gaseous and other bodies which are more or less soluble. The destruction of cellulose, the chief constituent of the woody fibre from which paper is made, is chiefly effected under anaërobic conditions by the *Bacillus amylobacter*. If the sewage is too long confined putrefaction sets in, with the production of a relatively large proportion of sulphuretted hydrogen and other offensive products, the presence of which not only causes a nuisance, but actually impedes the action of the aërobic bacteria at a later stage of the process of purification. Confinement in a closed tank, therefore, should be sufficiently long to liquefy the maximum amount of insoluble organic matter without allowing the putrefactive bacteria to develop sufficiently to render the odour of the liquid decidedly offensive. The sewage, septicised or not septicised, is in all cases finally purified by certain aërobic bacteria, usually grouped together and called "nitrifying organisms." The changes are generally believed to take place in two stages. In the first the various ammonia compounds and derivatives are decomposed with the production of nitrites, and these acting on a further portion of the ammonia and its derivatives form stable organic compounds and give rise to evolution of gaseous nitrogen. In the later stage allied bacteria effect further oxidation, and nitrates appear in the effluent, and the more completely the action is effected the less ammonia and organic matter will remain in the effluent and the greater the amount of nitrates which will be present. The bacteria causing typhoid fever and cholera have rarely, if ever, been found in sewage. Attempts to isolate the former from the sewage of a hospital containing many typhoid fever patients resulted in failure. Searching for them, however, has been likened to seeking a needle in a stack of hay, but when introduced in laboratory experiments their presence can be demonstrated without any great difficulty. If the results of various bacteriologists are to be trusted, the typhoid bacillus lives longer in sewage than in pure water, and at the present time we are not in a position to say that any bacterial system of purification destroys the germs of typhoid fever or of cholera, though there can be little doubt that the number of such germs in a sewage effluent will be few relative to those in the original sewage. Certain bacteria appear only to thrive in the presence of animal matter undergoing decomposition, and these are of especial importance, since the detection of the pollution of potable water by minute quantities of sewage depends entirely upon the isolation from the water of one or more of these organisms. Many of these bacteria are either difficult to isolate or difficult to identify, or occur in comparatively small numbers, hence they are of little use as an index of pollution. On the other hand, the *Bacillus coli*, the *Bacillus enteritidis sporogenes*, and the various streptococci occur in considerable numbers, are fairly easily isolated and identified, and their presence in a water can be ascertained. Their presence not only indicates sewage pollution, but from the numbers it is possible for an approximate estimate to be formed of the extent of the contamination. Klein and Houston, in examining the London sewage at Barking outfall, found these organisms in the numbers following, per c.c. of sewage:—

Bacillus coli communis .	100,000 to 800,000
Streptococci . . .	1,000 to 10,000
Spores of *bacillus enteritidis sporogenes* . .	100 to 2,000

There are many varieties of the *Bacillus coli*, and if all were included the numbers above given would have to be considerably increased. On the other hand, the characteristics of the

Bacillus coli communis can be so defined as to considerably decrease the apparent number found in sewage. The number of bacteria found in sewage effluents varies enormously, but apparently those which do occur are typical of the original sewage. The numbers may be decreased, but the proportions of the more easily recognisable organisms are not markedly altered. An effluent may be quite satisfactory from the chemical point of view, yet contain hundreds of thousands of bacteria. These can, of course, be reduced enormously by sand filtration or by passing through suitable land. Where it may be necessary to remove practically all the bacteria, as when the effluent has to be discharged somewhat near the intake of a waterworks or near shellfish layings, their destruction can be ensured by the action of very small quantities of chlorine, either as gas or in solution, or as "chloride of lime"; and as the excess of this chemical can easily be destroyed, it is probable that this process will in the near future be employed in special cases. J. C. T.

Micro-organisms in Water. — Strictly speaking the term micro-organism includes all the forms of animal and vegetable life which require the aid of a powerful lense or of a microscope for their identification, and includes forms most diverse in character, but usually it is limited to the very minute fungi called "bacteria" (*vide* section on "Germs of Disease"). These bacteria are of paramount importance, since they are the only organisms which infest all waters and which are capable of rendering it a vehicle of infection. It is doubtful whether any natural water is free from bacteria. They are found in the water from the deepest wells and purest springs, though in limited number, but it is rare to find less than ten in one cubic centimetre of water from any source. In such pure waters they have a tendency to multiply somewhat rapidly if the water is kept twelve to twenty-four hours before being examined, and especially if the water attains a temperature exceeding 50° F. At lower temperatures growth may be retarded or prevented, hence in sending samples of water for bacteriological examination it is advisable to pack the bottle in a box containing a little ice. In waters which, when taken, contain very large numbers of bacteria, the opposite results may ensue, the number present continuously decreasing. In pure water, only bacilli (rod-shaped bacteria) are found, in impure waters cocci (spherical bacteria) are occasionally found. As bacteria flourish on damp surfaces, in soil and in impure water, and are also found in the air, obviously they gain admission to water in many different ways. Fortunately very many are unable to live long in this medium, especially if exposed to light; others may live for many days without showing any marked tendency to increase in numbers, whilst others appear to find in water their normal habitat and may live in it for an indefinite period, their increase being probably limited only by the amount of nutriment present in solution. Belonging to the fungi, they can only grow and multiply when the water contains organic matter in solution, and as pure waters contain an infinitesimal trace of such matter very few bacteria are as a rule found therein. On the other hand, waters rich in organic matter, from whatever source derived, generally contain an abundance of bacteria. When bacteriology was in its infancy stress was laid upon the relative abundance of bacteria in water as a test of quality, a water containing few bacteria, say less than 500 or 1,000 per cubic centimetre, being classed as good, whilst one containing 5,000 and upwards would be regarded as polluted. The bacterial contents of waters from divers sources at different seasons vary so enormously that these arbitrary standards can no longer be accepted, and numbers now are only regarded as of primary importance as a test of efficient filtration. The standard suggested by Koch as an indication of efficient filtration was the presence of less than 100 bacteria per cubic centimetre, such bacteria being enumerated from the colonies growing

on nutrient jelly in forty-eight hours at a temperature of 70° F. In this country the same number of colonies is accepted, but the growth is allowed to continue for three days. This frequently makes an enormous difference, as slow-growing bacteria may develop no visible colonies in two days, but may produce colonies visible in three days. The present standard is therefore higher than that suggested by Koch. Of more importance than the mere numbers is the nature of the bacteria present. Of the large number of species found in waters, there are certain varieties which are rarely, if ever, found in really good potable waters, but which are almost invariably present in water from moorland surface on which cattle are grazed, in water from fertile and manured lands, and water containing sewage. These bacteria are of animal origin and flourish best at a temperature approximating to that of the human body, whereas the true water bacteria grow slowly, if at all, at that temperature. If water is mixed with a jelly made of agar instead of gelatine, so that it will withstand a temperature of 98° F. without melting, and incubated for twenty-four hours, the true water bacteria do not multiply with sufficient rapidity to produce visible colonies, whereas the foreign bacteria produce such colonies, and the number produced serves as an indication of the quality of the water. As a rule pure waters produce few such colonies, whilst polluted waters produce many, but for reasons, difficult as yet of explanation, this test alone cannot be relied upon. As a confirmatory test, however, it is of considerable value. The bacteria of typhoid fever and cholera are those most chiefly to be dreaded in water, but it is only on very rare occasions that they have been discovered, even when outbreaks of these diseases have been traced to their presence. It is practically useless, therefore, attempting to isolate them. Moreover, it is far more important that the possibility of such pollution should be discovered, since it is too late to discover them when present, as their presence will have been already demonstrated by an outbreak of disease. These bacteria can only gain access to water with excrementary matter, and the presence of such filth therefore indicates the possibility of specific pollution. Reference to the article on "MICRO-ORGANISMS IN SEWAGE" will show that recent sewage always contains certain bacteria which are easily isolated and identified, and which never occur associated save in manurial matter. Unfortunately they occur in the excrement of nearly all mammals and fishes as well as in human excrement, so that their presence does not always necessarily indicate contamination of a dangerous character, since so far as we know, animals do not suffer from typhoid fever or cholera and cannot therefore impart those diseases to man. The bacteria referred to are the *Bacillus coli communis* and its varieties, the spore-bearing *Bacillus enteritidis sporogenes*, and *cocci* occurring in chains (streptococci). Fresh domestic sewage generally contains about 1,000,000 *bacillus coli* in a cubic centimetre and from 10,000 upwards of the other micro-organisms mentioned. If, therefore, water is contaminated with one-millionth part of sewage, the pollution can be easily detected bacteriologically. This test is far more delicate than chemical analysis, which may fail to detect one part of sewage in 1,000 of water. Moorland waters and springs in fissured formations fed from moorlands almost invariably contain the *Bacillus coli* derived from animals of various kinds found on the watershed, and wild-fowl may pollute the water of a large reservoir. As a rule, however, good moorland waters do not yield more than one *Bacillus coli* in 10 cubic centimetres, and this standard is usually accepted for such waters. Deep well waters come under a different category and should not contain the *Bacillus coli* in 25 cubic centimetres, but on occasions the organism is found in deep well waters in greater relative abundance although no possible source of contamination is discoverable. If present in very small numbers and unassociated with streptococci and the spores of the *Bacillus enteritidis*

sporogenes, their presence has probably no significance, but if these bacteria are also found associated in the same sample the presence of pollution derived from manurial matter may be regarded as decisively proved. Other bacteria, such as the *Proteus vulgaris*, *Bacillus subtilis* and *Bacillus mycoides*, are frequently found in waters, and indicate contamination by impure surface water or dust, but so far as is at present known they have no special significance, beyond emphasising the necessity for careful watchfulness and supervision over the source of supply.

J. C. T.

Middens.—(*See* "PRIVIES.")

Mortar; Composition and Strength of.—Builder's mortar is a mixture of lime and sand or other gritty substance, such as burnt clay or clinker, ground to a fine powder, the proportions usually being one volume of unslaked lime to three volumes of sand or grit. All limes are not alike, and the differences between them, as well as those between different samples of sand and grit, have given rise to much controversy and misunderstanding. The various limes are known as (1) fat limes, *i.e.*, obtained from the best quality chalk, limestone, &c., and contain from 90 to nearly 100 % of chemically pure calcium oxide (CaO); (2) feebly hydraulic limes such as greystone lime, which contains about 80 % of calcium oxide; and (3) strong hydraulic limes, such as the blue lias lime, containing about 60 % of calcium oxide. The fat limes are used as a "putty" for interior walls, &c., and the feebly hydraulic and strongly hydraulic limes for mixing with sand to form mortar for bonding bricks.

The character of the sand and grit is equally a matter of importance, and care should be taken that this is either good clean sand or crushed clinker, free from earthy matter, by which term is meant unburnt clay, garden mould, or road sweepings, &c. The presence of a small quantity of natural clay in a sand has been supposed to be detrimental, but recent researches have demonstrated that if the quantity does not exceed 10 % by weight of the dry sand a decided advantage in the resulting strength of the mortar is obtained, which is confirmed by the analysis of numerous samples of Roman mortars collected from the London Wall, Allington Castle, and other authenticated ancient structures whose walls have stood the test of time. For instance, three samples from Allington Castle, collected by Mr. W. D. Caroë, F.R.I.B.A., near Maidstone, *circa* twelfth and thirteenth centuries, contained highly ferruginous clay equal to 8·6 %, 3·66 %, and 4·0 % respectively in the sand, the sample containing 8·6 % having a crushing strength of 144 per square inch, and that containing 3·66 % 90 lbs. A sample of mortar collected by the writer from the Roman wall under Leadenhall Market in the presence of the City Surveyor, Mr. Perks, and Mr. Max Clarke, F.R.I.B.A., was found to contain 3·62 % of ferruginous clay calculated on the dry sand, and had a crushing strength of about 164 lbs. per square inch, one piece resisting even 500 lbs. per square inch. These results confirm the series of experiments submitted by the writer to the Royal Institute of British Architects, December, 1906.

Two especial points to be observed in the selection and use of lime for mortar are: (1) that the lime should have been well burnt to drive off all carbonic acid and thus secure the whole of the lime being in an active state; and (2) that the lime should be thoroughly slaked before being used. In order to ensure this it is the practice of the best builders to slake the lime for a week or more before use. Unfortunately the introduction of the mortar mill has had a tendency to introduce unslaked lime into the mill with the sand, crushing the whole together and then employing the resulting semi-slaked lime on the work without further delay. Bye-laws which have been made by local authorities have specified so much lime and so much sand or burnt ballast, the latter to be crushed in a mill. The builder naturally adds the two together accordingly, and the mortar is made. In one case, coming under the writer's experience, the builder being

aware that the lime should be first slaked dry-slaked it, and instructed his men to use the materials in the proportions laid down in the bye-laws. The volume of slaked lime is greater than that of the unslaked lime, the expansion being about 1 to $1\frac{1}{2}$ or $1\frac{3}{4}$. This was overlooked, and consequently each "shovelful" contained less than would have been the case if the lime had been used unslaked in accordance with the bye-laws. This oversight, which led to much trouble, might have been avoided if the bye-laws had been sufficiently explicit. The fineness of the sand or grit has considerable influence on the resulting strength of the mortar. A coarse sand requires more lime than a fine one to yield the maximum strength, which, however, is from two to three times that obtained with the finer sand and normal quantity of a given lime. This difference is entirely due to the nature of the voids in the sand which must be thoroughly filled by fine sand and grit, clay, or an excess of lime. If this is not done there is a lack of that intimate contact between particle and particle which is so essential in all cases where strength of adhesion is required. In the case of three samples of mortar made with sands having 23, 28, and 40% of voids respectively, the crushing strength of the mortar at the end of one month was 154, 155, and 70 lbs. per cubic inch respectively, the tensile strength falling from 41 lbs. per square inch to 32 and 28 lbs. for the respective samples. It is therefore important to ascertain, in all cases where the greatest strength is required, the percentage volume of voids in any particular sand proposed to be employed. The most simple method of ascertaining the voids is to place the sand in a glass cylinder marked in separate divisions up to 200 measures. Run the sand in its natural condition into the cylinder, so that when shaken down into its naturally compressed condition it measures 100 divisions. Then remove the sand and fill up to the 100 mark with clean water. Now gradually pour the sand into the water and shake down. Note the height to which the water rises and the volume the sand now measures under water. The total volume thus measured, minus the sum of the volumes of the water taken and the volume of the sand as measured under water, gives the voids in terms of percentage volume thus:—

Sand taken	100 c.c.	
Water ,, ...	100 ,,	
Volume of mixed sand and water =	163·7 ,,	
,, sand under water =	99·0 ,,	
Voids equal sand under water plus water ..		199·0
Less volume of mixed sand and water ..		163·7
Per cent. ..		35·3

One of the questions requiring an answer from the analyst is that of the original composition of the mortar in terms of volumes of sand and grit to lime. This cannot be stated with perfect accuracy unless samples of the original materials are available, but a close approximation may be made by the physical examination of the constituents, for which purpose the lime is separated from the sand and grit, and the weight of the latter per cubic foot noted. The lime in the absence of definite data may be assumed to have been greystone lime of 80% CaO and weighing 40 lbs. per cubic foot, but great caution must be exercised, as considerable variations arise. The weight of the commercial lime thus found has now to be increased by calculation in the ratio of the weights per cubic foot of the lime to that of the sand and grit which has been already obtained. Thus 1 cu. ft. of lime weighing 40 lbs. will have the same volume as that occupied by 90 or 100 lbs. of sand or grit, as the case may be, or of 50 or 60 lbs. of clinker, &c.

The following illustrates the method:

Lime (CaO) per cent. ..	5·71	
Equal to commercial lime of 80% (CaO) ..	7·15 and $\frac{107 \times 7{\cdot}15}{40} = 19{\cdot}1$	
Sand and grit per cent...	91·13	
Moist sand and grit as used	107·0	
Commercial lime to moist sand and grit, by weight	7·15 :	107
Commercial lime to moist sand and grit, by volume	19·1 :	107
or	1 :	5·6

If the lime had been measured as dry slaked lime its volume would have been increased in the ratio of 1 : ·53, so that the ratio would have been 1·53 to 5·6 or 1 : 3·66.

The setting of mortar was ascribed by the late Professor Graham to the fact that "on drying the mortar binds the stones between which it is interposed, and its own articles cohere so as to form a hard mass solely by the attraction of aggregation, for no chemical combination takes place between the lime and the sand, and the stones are simply united as two pieces of wood are by glue." "From the minute division of the silica and alumina in hydraulic mortar their combination with lime is more likely to occur than in ordinary mortar. Still the fixing of hydraulic mortar seems to be due chiefly to the fixation of water and formation of a solid hydrate like gypsum." This agrees with the experiments of the writer on mortar made with materials free from soluble silica. After twelve months no trace of soluble silica could be detected as would have been the case if any combination between the silica and the lime had taken place. This result agrees with analyses of ancient mortars in which the soluble silica is no more than would be found in the fresh mortar. For instance, the three samples from Allington Castle already referred to contained only 1·20, 0·70, and 1·00 % of soluble silica; whilst that from the London Roman Wall contained only 0·30 %. In many cases where pozzuolana or trass has been employed the soluble silica will be high, and this fact has doubtless given rise to much misapprehension on the point.

The manner of slaking lime for making mortar often receives too little attention. According to Mr. Clifford Richardson, slaking fat limes with two volumes of water added at once is the most advantageous procedure, and that but a small departure from these proportions on either side will result in forming a less satisfactory paste. With poorer limes much smaller volumes of water should be used. Clifford Richardson has arrived at the following general conclusions: "It appears that fat limes should be slaked with 2·5 volumes of water, added at once in a closed box, to obtain the best and largest amount of good paste; and with this three times the volume of the lime in the shape of moist sand may be mixed for fine work, such as pointing, plastering, and in places exposed to dampness, and that five volumes of sand is not too much for ordinary brick-work.

"The amount of mortar which a barrel of lime, of average weight, under the same conditions as in the experiments, would yield, is:—

Parts Sand.	Parts Water.	Cubic Feet.
3	2·5	16·5
4	2·5	20·6
5	2·5	24·8

or 4 cu. ft. of lime with 2·5 parts of water, and four volumes of sand would yield 22 cu. ft. of mortar which, according to authorities, is sufficient to lay 1,000 bricks in ordinary brick-work with coarsely drawn joints. With more compact work one barrel of lime will lay 1,000 bricks. A barrel of poor or magnesian lime will not yield more than three-quarters of these quantities." W. J. D.

Mortuaries.—The Public Health Act, 1875, provides that any local authority may, and if required by the Local Government Board shall, provide and fit up a proper place for the reception of dead bodies before interment, and may make bye-laws with respect to the management and charges for its use; they may also provide for the decent and economical interment at charges to be fixed by such bye-laws of any dead body which may be received into a mortuary. Any local authority may provide and maintain a proper place (other than a mortuary) for the reception of dead bodies during the time required to conduct any *post-mortem* examination ordered by a coroner, and may make regulations with respect to the management of such place; and where any such place has been provided, a coroner may order the removal of the body to and from such place for carrying out such *post-mortem* examination. It is not infre-

quently found that a public mortuary forms part of the municipal disinfecting station; experience has shown that it is a wise course to adopt, as it is often found necessary to destroy filthy and infected clothing taken from an unclean body. A public mortuary, to which is attached the coroner's court, should comprise a mortuary fitted with slabs or receptacles for the reception of dead bodies, mortuary for infected bodies, *post-mortem* room, with a store, w.c., and lavatory adjoining, viewing lobby, shell store, doctor's room, attendant's room, and the coroner's court. The Battersea Disinfecting Station and Coroner's Court is a well-arranged building of this character. In the construction of these buildings the principal features are—plenty of light, good drainage, and perfect ventilation. The latter is of the utmost importance, there being a certain amount of organic matter given off from bodies which lie in the mortuary. In the construction care should be taken to avoid any materials which will harbour dust or dirt. The internal walls should be faced with white glazed bricks, and the floors covered with some hard substance, the intersection of the floor and wall being rounded. The doors should be of oak, solid panelled, and the ceilings plastered and then painted and varnished. The *post-mortem* room should be lighted from the roof, having a northern aspect. It should adjoin the mortuary so that a body may be easily removed from one apartment to the other. This room should be fitted with a vitreous enamelled operating table, sinks, and lavatory. On the walls a sufficient number of glass shelves should be provided for the storage of bottles, &c. They should be of polished plate glass, fixed clear of the walls on vitreous enamelled iron cantilevers built into the wall. The sinks and lavatory should have a good supply of hot and cold water. When the mortuary adjoins the disinfecting station the supply of hot water is easily obtained. When no supply of hot water is obtainable, then suitable geysers should be provided. The provision for viewing bodies varies; in some cases a small apartment is arranged adjoining the mortuary, into which the body is removed; in other cases a portion of the mortuary is formed with a window and the body placed on a slab immediately in front. In all cases the viewing room should be so arranged that the jury have not to walk any great distance from the coroner's court for the purpose of inspecting a body. The coroner's court, which is provided in connection with the mortuary, should be within easy access from the main entrance to the building. In addition to the court, waiting-rooms should be provided for the convenience of witnesses or prisoners.

A. C. F.

Municipal and County Engineers, Incorporated Association of.—The Association was founded in 1873 with the following objects:—"The promotion and interchange among its members of the knowledge and practice which falls within the department of an engineer and surveyor engaged in the discharge of the duties imposed by the Public Health and Local Government Acts." The Association has for its objects at the present day (*inter alia*):—(1.) The promotion of the science and practice of engineering as applied to the health and improvement of countries, towns, urban and rural districts. (2.) The promotion of the professional rights, interests, powers, and privileges of county, urban, and rural engineers, the improvement of the professional status, and the extension and interchange of professional knowledge and practice. (3.) The examination of persons in engineering, surveying, building construction, sanitary science and works, and in local government, municipal and sanitary law, and the granting of certificates of having passed the examination in the above subjects to candidates. At its inception in 1873 membership was restricted to those holding chief appointments as engineers and surveyors to local authorities; but in 1886 a class of graduates was formed, the qualifications for election to this class being the passing of the examination, which was instituted in that

year. This was followed in 1901 by the inclusion of "Associates," elections to this class being made only from professional men occupying assistantships in the municipal engineering profession. Finally a class of "Associate-Members" was formed for professional men holding minor chief appointments or important assistantships.

In 1890 the Association applied for and received the sanction of the Board of Trade to its incorporation under the Companies' Acts, and county engineers and surveyors became eligible for full membership.

In 1905 a schedule of educational requirements was adopted for candidates for permission to sit for the examination.

1,472 candidates have been permitted to sit for examination, of whom 713 qualified for the Association's testamur. Members pay an entrance fee of £1 11*s.* 6*d.*, and an annual subscription of £1 11*s.* 6*d.* Associate members (excepting those holding the testamur of the Association, who pay no entrance fee) pay an entrance fee of £1 5*s.*, and an annual subscription of £1 5*s.* Associates (excepting those holding the testamur of the Association, who pay no entrance fee) pay an entrance fee of £1 1*s.*, and an annual subscription of £1 1*s.* Graduates pay an annual subscription of 15*s.* The Association holds meetings, when professional papers are read, and periodically pays official visits to different centres in order to inspect municipal works of all descriptions. Papers read are published in the annual "Proceedings." The last annual report states: "The Association consists of 8 honorary members, 818 ordinary members, 78 associate members, 127 associates, and 170 graduates, making a total of 1,201. The Association publishes quarterly a digest of law cases, that are of interest to the municipal engineer."

T. C.

Municipal Engineers, Institution of.—The Institution of Municipal Engineers was founded in May, 1908, with the object of providing a body representative of the profession of municipal engineering in all its branches, or, to quote the words of the resolution:—"That, recognising the great possibilities of an 'Institution of Municipal Engineers' in the widest sense of the term, men holding important appointments under local authorities, such as electrical engineers, gas engineers, mechanical engineers, and water engineers, shall be eligible for election to membership of the Institution."

A most important feature of the Institution's programme is the appointment of district committees in specific centres, each committee having its local chairman (who is *ex-officio* a member of the Council) and local honorary secretary. By the establishment of these committees the policy of the Institution is determined by the majority of its members.

The carrying out of practical work being considered as the most important qualification for admission to membership, no examination is necessary precedent to membership. It is recognised, however, that many members may desire to have their special knowledge of some branch of municipal engineering tested, and it is proposed, therefore, to hold examinations of a severely practical character, for which certificates will be granted, in the chief branches of professional work.

It has been decided that membership of the Institution shall be announced by the affixing of the letters "M.I.Mun.E." to a member's name. The agnomen is not intended to afford proof of anything beyond membership of the Institution. A diploma of membership is granted upon election. The Institution publishes a quarterly "Journal," and has established a lending library of technical works.

The offices of the Institution are at 39, Victoria Street, Westminster, London, S.W.

B. W.

Municipal and County Engineers and Surveyors.—The term "Municipal Engineer" is unknown to the law, but it has become an accepted usage to denote by the term "Municipal and County Engineers and

Surveyors" the officials who are responsible for, speaking broadly, the constructional work carried out by local authorities. Their main duties are thus of an engineering character, although they have also much work to do of an architectural or purely administrative type. They are known to the law as "surveyors"—such a description is a misnomer. The profession of a surveyor is defined in the charter of the Surveyors' Institution as "the art of determining the value of all descriptions of landed and house property, and of various interests therein; the practice of managing and developing estates; and the science of admeasuring and delineating the physical features of the earth, and of measuring and estimating artificers' work." If this definition be considered it will be seen that most of the multifarious and widely-divergent duties of a municipal surveyor are outside the province of the profession of a "surveyor" altogether. For the present purpose it is convenient to speak of the officials dealt with as "Public Health Engineers," and it should be remembered that this title is coined for the purposes of the moment, and is meant to include county surveyors and the engineers to municipalities and to borough, urban and rural authorities.

Public health engineers hold their offices under different statutes according to the kind of authority by which they are appointed. The county surveyor is appointed by the county council under their general powers. The duties of this official are mainly concerned with the maintenance and repair of main roads and bridges, and he is a direct descendant of the surveyors who were first appointed under the Statute of Bridges (22 Henry VIII. c. 5), by which it was enacted ". . . that the same justices, or four of them, within the limits of their commissions and authorities, shall also have power and authority to name and appoint two surveyors, which shall see every such decayed bridge repaired and amended from time to time, as often as need shall require. . . ." The surveyor to an urban authority (*i.e.*, a corporation or urban district council) is appointed under section 189 of the Public Health Act, 1875. The same section fixes the salary as such amount "as the urban authority may think proper," and further provides that the surveyor shall be removable by the urban authority at their pleasure. The effect of this section is that the surveyor is removable from office at the pleasure of an urban authority, whereas a medical officer of health or inspector of nuisances is not so removable without the consent of the Local Government Board. Inasmuch, however, as the nature of the surveyor's duties is such as frequently to lead a conscientious official into collision with his employers, and the effective administration of sanitary legislation eminently requires independent executive officers, it would appear to be highly desirable that in the matter of Government protection the surveyor should be placed on an equality with the medical officer of health and inspector of nuisances.

The surveyors to rural authorities are appointed under section 190 of the Public Health Act, 1875; and the surveyors to the Metropolitan borough councils hold their office under section 62 of the Metropolis Management Act, 1855.

It is provided by section 192 of the Public Health Act, 1875, that the same person may be both surveyor and inspector of nuisances, but the Local Government Board do not generally assent to a combination of these offices in a district of large area or population.

The duties of a public health engineer, though they vary according to the kind of authority which that official serves may, and generally do, involve responsibility for branches of work which have been conveniently tabulated by Mr. H. Percy Boulnois, M.Inst.C.E., a former City Engineer of Liverpool, under the following main divisions and sub-divisions:—

ENGINEERING.

Bridges

Sewerage
- Water Carriage
  - Partially Separate System
  - Separate System
  - Complete System
- Dry System
  - Earth Closets
  - Tubs
  - Pails
  - Middens
- Disposal
  - Irrigation
  - Filtration
  - Precipitation

Water
- Collection
  - Rivers
  - Springs
  - Gathering Grounds
  - Deep Wells
- Supply
  - Constant
    - Pumping
  - Intermittent
    - Gravitation

Road Making
- Traffic
- Macadam
  - Road Rolling
- Paving
  - Stone Setts
  - Wood
  - Asphalte
  - Bricks
- Footways

Prevention of Floods

Tramways
- Cable
- Electric
- Steam
- Horse
- Compressed Air

Street Lighting
- Electricity
- Gas

ARCHITECTURE.

Building Surveyor.
- Dangerous Structures
  - Safety of Theatres
- Inspection of Plans
  - Streets in Progress
    - Defects
    - House Drainage
  - Buildings in Progress
    - Factories

Corporation Buildings
- Municipal Offices
  - Police Stations
  - Fire Stations
- Artizans' Dwellings
  - Public Baths
  - Mortuaries
- Markets
  - Abattoirs

LAW.

Electricity Acts

Lighting Orders

Sanitary Acts
- Special Acts
- Bye-laws

Gas and Water Acts

Parliamentary Work
- Oppositions and Promotions
- Extension of Boundaries
- L. G. B. Inquiries

Arbitrations

Contracts

MISCELLANEOUS.

Removal of Snow

Scavenging
- Collection
- Disposal

Road Watering

Hygiene

Landscape Gardening
- Recreation Grounds
- Cemeteries
- Parks

Disinfection

SURVEYING.

Quantity Surveying — Field Work — Valuations

Levelling

ADMINISTRATION.

Staff — Contracts — Committee

Tradesmen's Accounts — Wages — Statistics — Reports — Records

Correspondence

Except in the rarest instances the public health engineer is not in virtue of his office entitled to superannuation. By the Superannuation (Metropolis) Act, 1866, however, it is provided that the London County Council and the Metropolitan borough councils may, at their discretion, grant to any officer in their service who shall become incapable of discharging the duties of his office with efficiency by reason of permanent infirmity of mind or body, or of old age, upon his resigning or otherwise ceasing to hold his office, an annual allowance not exceeding two-thirds of his then salary. It is difficult to see any distinction for the purpose of superannuation between a poor law official (who is entitled by statute to a pension) and a municipal official, and it is to be hoped that the claims of the latter will soon be recognised by Parliament, especially as private Acts, on the lines of the Poor Law Officers (Superannuation) Act, 1896, have in recent years been secured by several Metropolitan boroughs individually.

The usual method of entering the profession of a public health engineer is by serving a pupilage of at least three years. The premiums vary from about £75 to £300, according to the size of the town or district and the professional standing of the engineer. The next step after pupilage is usually an appointment as "junior assistant," at a commencing salary of £60 or £70 a year, and after intermediate stages have been passed an appointment as chief assistant should be secured at an annual salary of from £130 to £250. Finally a chief appointment may be obtained, the salaries varying from a small sum up to £1,000 or £1,500 a year which is given only in the largest cities. Full information as to these matters will be found in a little book entitled "How to become a Municipal Engineer," by J. Freebairn Stow, late Engineer and Surveyor to the Uxbridge Rural District Council.

It has become increasingly necessary in recent years that the pupil or junior assistant should pass some of the examinations of the recognised professional examining bodies, *e.g.*, The Incorporated Association of Municipal and County Engineers, The Institution of Municipal Engineers, The Insitution of Civil Engineers, The Sanitary Institute, The Surveyors' Institution, &c. If he does not do so, he will find that he is at a considerable disadvantage in the keen competition which invariably takes place for any good appointment.

Public health engineers have two professional organisations: The Incorporated Association of Municipal and County Engineers (q.v.), and the Institution of Municipal Engineers (q.v.). E. G. T. &. G. T.

Nitrification.—In a sanitary sense, means the complete oxidation of the nitrogen in organic matter by its conversion into nitrate. The process naturally occurs in stages, (*a*) fermentation into ammonia; (*b*) nitrosification or intermediate oxidation of this into nitrite; (*c*) nitrification proper, or final oxidation, into nitrate. The reverse change, denitrification takes place often when aëration is deficient. Each reaction is occasioned by different

species of bacteria, some of them working in *symbiosis*, the condition when two or more species act together and effect decompositions which neither of them could do separately. Whenever we find a final filter acting badly, from deficient aëration or other cause, the fault is at once indicated by the appearance of a high proportion of nitrites, as nitrosification is not nearly so difficult a process to manage as the nitrification which should naturally follow. The organisms causing the latter, notably Omeliansky's *nitrobacter*, require for activity that the ordinary sewage organic matter and ammonia should have been considerably reduced, hence the advantage of a filter in successive zones like that of Scott-Moncrieff. But the presence of humus colloids appears to preserve the vitality of nitric organisms as it does in soils, so that, in an effluent which is properly prepared and well aërated, nitrification can often be encouraged by seeding with a small quantity of fertile garden soil. It is always necessary that a base should be present to combine with the acid formed, therefore in a sewage farm if the ground be devoid of lime, it must be added. Liquids to be nitrified must not be too strong or too alkaline, and large quantities of chlorides, as in sea-water, are unfavourable, while iron salts assist the process. Darkness is advisable, and a free supply of air is always necessary; in unaërated filter beds a large quantity of carbonic acid accumulates and nitrification is hindered. It is important to notice that at the same time as the nitrogen in sewage is converted into nitrous and nitric acid, the dissolved carbonaceous matters are also oxidised into carbonic acid, giving a double improvement. The nitrates and nitrites contain "available oxygen" which by the process of denitrification can supplement the dissolved oxygen of a stream into which sewage may flow, in oxidising the organic matters. Hence in the case of any stream and (clear) effluent, if we ascertain the respective volumes, and the amounts of oxidised nitrogen and organic carbon (by the "oxygen consumed" figure), we shall obtain a ratio showing what volume can be discharged without fouling. A highly nitrated and well-aërated effluent can actually improve many rivers, and in irrigation has a strong fertilizing power. (*See* "OXIDATION OF SEWAGE.") S. R.

Norton's Tube Wells.—(*See* "ABYSSINIAN WELLS.")

Notification of Diseases.—(*See* "ZYMOTIC DISEASES.")

Ohio Water Supply and Sewage Disposal.—The Ohio State Board of Health was created in 1886. The Board was given the usual general powers regarding the control of epidemics and infectious diseases. It is composed of seven members, one being appointed by the Governor each year. The Board was also given advisory powers regarding public water supplies and sewerage; but had no absolute authority over these. In 1893, at the time of the cholera epidemic at Hamburg, when some cholera cases were being imported to the United States, the Ohio State Board of Health, realising the importance of protecting the public water supplies, asked the legislature for increased authority along these lines. As a result, there was passed in 1893 the following law: "It (the State Board of Health) shall respond promptly, when called upon by the State or local governments and municipal or township boards of health to investigate and report upon the water supply, sewerage, disposal of excreta, heating, plumbing, or ventilation of any place or public building; and no city, village, corporation, or person shall introduce a public water supply or system of sewerage, or change or extend any public water supply or outlet of any system of sewerage now in use, unless the proposed source of such water supply or outlet for such sewerage system shall have been submitted to and received the approval of the State Board of Health." In 1908, with a view to perfecting the above law, it was amended by the legislature to read as follows:

"No city, village, public institution, corporation, or person shall provide or install for public use, a water supply or sewerage system, or purification works for a water supply or sewage of a municipal, corporation, or public institution, or make a change in the water supply, waterworks intake, water purification works of a municipal, corporation, or public institution, until the plans therefore have been submitted to and approved by the State Board of Health. No city, village, corporation or person shall establish a garbage disposal or manufacturing plant having a liquid waste which may enter any stream within twenty miles above the intake of a public water supply until the location of such garbage or manufacturing plant, including plans for disposing of such liquid waste, is approved by the State Board of Health. Whoever violates any provision of this section shall be fined not less than one hundred nor more than five hundred dollars." Since 1893, therefore, it has been necessary that all plans for new projects for public water supplies or sewerage be approved by the Board. In regard to works in existence previous to 1893, the Board has had until the year 1908 no jurisdiction, except to investigate and point out to local officials any conditions which need improvement. In 1898 legislation was enacted, authorising the State Board of Health to establish and maintain a laboratory for the chemical and bacteriological examination of public water supplies and of sewage effluents; in addition, pathological work was provided for. The Board was directed to annually examine and report upon the condition of public water supplies. About this time the Board also established an engineering department for the purpose of making careful investigations of the proposed water supply and sewerage projects which came before it for consideration, as well as for studying the conditions of existing works. During the years 1897 to 1902, inclusive, the Board has, through its engineering department and laboratory, and with the aid of other temporary expert assistance, made a detailed study of the watersheds of all the principal rivers in the State. One or two watersheds were taken up each season. These studies included an investigation of all sources of pollution both from cities and villages, as well as from factories. All sewerage systems and waterworks were examined in detail, and the population using such works were determined. Chemical analyses of the rivers themselves were made at regular intervals, and the pollution of the water, in many instances, was thereby conclusively demonstrated. The results of these investigations, including maps and statistical information, will be found in the annual reports of the State Board of Health. These reports afford a very comprehensive view of Ohio conditions as regards stream pollution. Supplementary to the above work, stream gauging stations were established on certain rivers; and these were later maintained for several years by the United States Geological Survey, under the immediate direction of the engineer of the State Board of Health. Daily gauge readings and records of discharge, covering periods of from six months to three years, of some fifteen of the rivers of Ohio are now available. These have been of great service in studying sewerage problems and also in other work. During 1905 the Board, acting co-operatively with the Hydro-Economic Division of the United States Geological Survey, made a detailed study of the disposal of certain industrial wastes which had long been sources of complaint. Much valuable and practical information was gained in regard to the purification of dairy refuse, woollen mill waste, acid iron waste from tube works, and the refuse from distilleries. The work on this last was especially interesting, as a method was developed whereby the valuable ingredients in the refuse could be reclaimed at a very substantial profit to the distiller. In 1906, on account of the increased responsibilities of the Board, due to the many important projects for water supply and sewerage which were submitted to it for approval, the legislature made a special appropriation to enable it to increase its engineering and laboratory force sufficiently

to make a detailed examination of the construction, methods of operation and efficiency of all existing water and sewage purification works in the State. This special investigation consisted of a series of detailed and systematic examinations of all the water purification and sewage purification works in operation in the State of Ohio. One of the assistant engineers devoted his entire time to the water purification works and another to the sewage purification works. Each examination occupied usually two or three days, during which time a large number of samples of the raw and treated sewage or water were collected, and observations made on rates of filtration, chemicals used, and upon other features. The bacterial samples were all plated, and most of the other analytical work done, immediately following the collection of the samples, in the field. This avoided the undesirable feature of shipping the samples by express, and thus added a great deal to the value of the investigation. A full detailed report covering the investigation is published under the title, "Report of an Investigation of Water and Sewage Purification Plants in Ohio, 1906—1907." The investigation above described served to further equip the State Board of Health for the responsibilities which were placed upon it by the legislature in the spring of 1908. In April, 1908, there was passed a law, known as the Bense Act, conferring upon the State Board of Health the power to order, in each case with the approval of the Governor and Attorney-General, any city, village, or corporation to install a water or sewage purification plant whenever it is shown, after investigation and after granting full hearing to those interested, that such a plant is necessary. Existing works may be changed or enlarged through a similar procedure. The Act further empowers the State Board of Health to secure competent operators for water and sewage purification plants. If a community or corporation believes that any order of the State Board of Health is not just, then "the necessity for and reasonableness of such order" may be submitted to a commission of referee engineers who shall have power to affirm, modify, or reject such order; one of these referee engineers to be chosen by the community or corporation and the other by the State, and they to choose a third if necessary. The decision of this engineer commission is to be final. In this way a municipality or corporation has ample protection against the possibility of arbitrary or unjust orders, thus removing criticism made in the past of the placing of too much authority in the hands of a State Board of Health. An important feature of the Act and one which is essential to its enforcement is that clause which makes it possible for a city or village to appropriate money for water or sewage purification works in excess of the legal debt limit for other expenditures. The plea of poverty cannot, therefore, be used as an argument against making the necessary improvements in sanitary conditions of a community. In order to definitely place the responsibility for carrying out the orders of the State Board of Health, the members of departments or council of a municipality, or officers of a corporation are made personally responsible for carrying out orders of the State Board of Health, and are liable to a personal fine for failure to do so. The Act above discussed has been commented on most favourably by sanitary authorities in the United States as well as abroad. It is felt that this law is just and reasonable, and at the same time can be used to great advantage in preventing the pollution of streams.—

R. W. P.

Oil Engines.—Petroleum, or oil engines, like gas engines, are of the internal-combustion class and resemble the latter in that the power is generated by the explosion, in an engine cylinder operating on the Otto cycle, of a compressed inflammable gaseous mixture. In the oil engine this mixture is derived from the heavier mineral oils of which large supplies are now available, principally from America and Russia.

Some of the oils commonly used in oil

engines are Broxbourne Lighthouse (flash point[1] 152° F.), American Royal Daylight (flash point 76° F.), and "Russolene" (Russian ordinary) of flash point 82° F. These oils have an average calorific value per pound of about 21,000 British thermal units, and a specific gravity of about ·81. Texas and Roumanian fuel oils are also now being used in crude oil engines.

Principle of the Oil Engine.—The motive power of the oil engine is derived from the explosion, behind a piston within a cylinder, of a compressed gaseous mixture consisting of oil-vapour and air. The conditions are more complex than in the gas engine as the liquid oil has first to be vaporised within the engine

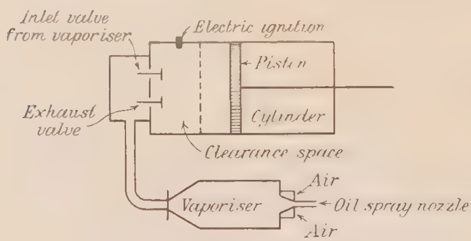


Fig. 1.

before the explosions needed to give the periodic impulses to the piston can take place, and, the design of a satisfactory "vaporiser" has proved the most difficult portion of the inventor's task. The main objects sought have been to satisfactorily vaporise the cheaper, heavier, and safer oils without clogging, and to provide for the proper admixture of air with the oil vapour. Three of the principal methods by which the vaporisation of the oil is accomplished in practice are shown diagrammatically in Figs. 1, 2 and 3. The arrangement illustrated in Fig. 1, is that adopted in the Priestman oil engine. The jet of oil, controlled by the engine governor, and a current of air, is mixed in a spraying-nozzle in such a way as to reduce the oil to an exceedingly fine spray received within a vaporising chamber which is heated by a jacket through which the engine exhaust fumes pass. During the outward or suction stroke, an additional supply of air, also regulated by the governor, enters the vaporiser where shown and forces the vaporised charge forward into the clearance space of the engine cylinder. Upon the return stroke of the piston, due to the impetus of the fly-wheel, the inflammable charge is compressed, becomes ignited by an electric spark at the moment of full compression, expands, doing work upon the piston, and finally is exhausted, the return stroke driving the products of combustion through the exhaust valve. The Priestman engine gives an explosion every second revolution, running on the ordinary Otto cycle common to most gas and oil engines. In this engine, the compression pressure of the gaseous mixture before admission is greatly reduced as the load reduces, and at very light loads the engine runs practically as a non-compression engine. The fuel consumption per indicated horse-power rises rapidly with the reduction of compression. This is shown, for example, in tests made by Prof. W. C. Unwin on a 9 I.H.P. engine working on Russolene oil, and in which the oil used per I.H.P. per hour was ·816 lb. (at full load) 1·063 lbs. (at half-load), and 5·734 lbs. (running light), the mean compression being, 26, 14·8, and 6 lbs. per square inch respectively. Another method of vaporising the oil is shown in Fig. 2. In this there is no sprayer, the oil being allowed to drop upon a spiral or corrugated surface of heated metal. The evaporation is assisted by part of the air supply necessary for forming the explosive mixture being drawn into the vaporiser over the heated surfaces. The suction stroke of the piston draws the mixture into the clearance space of the cylinder where, by means of the valve shown, it mixes with the additional air necessary to form an explosive mixture, and, upon the return stroke of the piston the charge is compressed and exploded, thus giving the forward impulse to the piston. In a modification of this method sometimes

[1] "Flash-point" = the temperature at which oil commences to give off inflammable vapour when under atmospheric pressure. The flashing-point increases as the density increases.

adopted, the air valve in the cylinder is not used, and the whole of the air supply necessary for the charge is drawn over the vaporising surfaces. Fig. 3 illustrates the method of vaporisation adopted in the "Hornsby-Akroyd" oil-engine, which is simple and effective. The vaporiser is a bottle-shaped chamber or extension of the cylinder, to which it is connected by a neck or contracted passage. It is

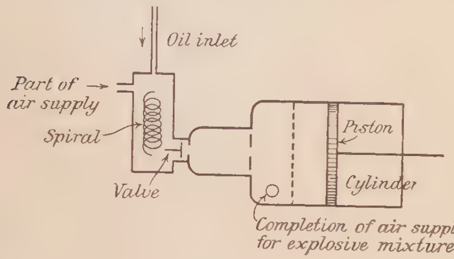


FIG. 2.

partially water-jacketed and, when first starting the engine, is heated by a lamp; afterwards, the combustion of the fuel within the engine is sufficient to maintain the temperature high enough to cause ignition of the vapour and air mixture. The oil supply is pumped from a tank formed in the base of the engine, by means of a small plunger pump, into the hot vaporiser during the outward or air-suction stroke. A little air also enters with the oil thus injected. Upon coming in contact with the heated surfaces the oil instantly spreads, is vaporised, and mixes with the products of combustion remaining from the previous charge, but the mixture does not contain sufficient oxygen for combustion. As the engine piston makes its outward or suction stroke the necessary additional air is drawn into the clearance space of the cylinder through a valve in the position shown but having no connection with the vaporising chamber. At the end of the outward stroke of the piston the cylinder is filled with air whilst the vaporiser remains charged with the mixture of oil vapour with some products of combustion. Upon the return or inward stroke of the piston, compression of the cylinder contents takes place, and the cylinder-air enters the vaporiser, thus supplying the necessary air for its combustion, until, at the point of full compression, ignition takes place and the resulting impulse is given to the piston. The time taken to start the engine is about nine minutes in the medium sizes. The vaporiser is the distinguishing feature of this type of engine, which requires neither hot tube, electric spark, nor slide valve with flame for the purpose of ignition. The Hornsby cheap-fuel oil engine is now made up to 500 B.H.P. The present writer has installed a 80 B.H.P. engine of this class for waterworks deep-well pumping purposes, and, in his experience, the cost of fuel per B.H.P. hour, using Texas or Roumanian oil at $2\frac{1}{2}d.$ per gallon, was ·2328 of a penny. There are many different makers of oil engines now on the market, amongst which may be mentioned the Blackstone, Britannia, Campbell, Crossley, Cundall, Gardner, Griffin, Robey, Ruston-Proctor, Samuelson, and Tangyes.

The "Diesel" oil engine, which takes its name from Herr Rudolph Diesel, has now become a motor of much scientific and commercial interest. It is an internal combustion engine intended for working with gaseous liquid or solid fuel, and is at present developed

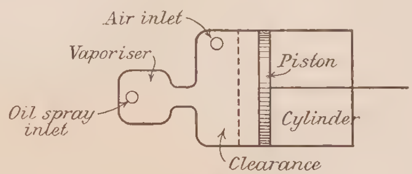


FIG. 3.

as an oil-engine working on the four-stroke cycle, and is built vertical. The cycle of operations, though not involving new principles, is very different from the process followed in the ordinary Otto engine. The leading distinguishing features of this engine are :—(1) The attainment within the cylinder of the necessary temperature for ignition of the charge by mechanical compression alone so that no extraneous igniting device such as incandescent tube, or electric spark is required ;

(2) The injection of the oil into the cylinder only after compression has been completed, and only during the first part of the working-stroke; (3) The oil is injected gradually into the highly heated air, each drop of the spray burning immediately and quietly, so that no explosion takes place.

Efficiency and Testing of Oil-Engines.—The cost of working oil-engines varies according to the class and cost of oil used, the mechanical and thermal efficiency of the engine, and its average working load. From trials of seven different makes of engines running at full load with "Russolene" oil costing $3\frac{3}{4}d.$ per gallon, the cost of one B.H.P. per hour was found to range from ·37*d.* to ·99*d.* The consumption of oil per B.H.P. showed an increase of about 32 % when at half-load. The total oil used at full load per B.H.P. hour varied from ·82 to 1·68 lbs., the B.H.P. of the engines ranged from about 5 to $8\frac{1}{2}$ B.H.P., and the mechanical efficiency from ·7 to ·9.

The Testing of Oil-Engines is carried out in a very similar manner to the testing of gas-engines. There is difficulty in obtaining satisfactory indicator diagrams, especially when the engine is being forced with excessive oil supply, so that wherever possible the performance of the engine should be taken on the B.H.P. as in the case of the gas-engine. The weight of oil used should be ascertained by measurement in a carefully calibrated tank, and where different classes of oil are used the calibration requires to be separately made for each owing to the varying density of the oils. The measurement of the air supply for combustion must also be made in order that the heat account for the engine may be made up. This is sometimes taken on the volume of the delivery of the air-pump where such is used, or may be approximately measured by an anemometer placed in a suitable air conduit or tank. W. H. M.

Open Spaces.—**Commons — Parks and Recreation Grounds and Gardens — Squares, Crescents, and other Inclosures — Disused Churchyards and Burial Grounds—Tree Planting in Thoroughfares — Laying Out and Maintaining Grounds—Rights of Way and Wayside Wastes—Statistics.**—The open space movement owes its origin to the continuous growth of population during the past 40 or 50 years in urban, as compared with rural areas, and to the consequent necessity for providing open spaces where fresh air, recreation, and exercise may be obtained by the ever-increasing number of town dwellers. The education of public opinion in regard to the importance of this subject has been largely due to the sustained efforts of certain societies, viz.: The Commons and Footpaths Preservation Society (1865), concerned chiefly with the preservation of common lands now to be found generally in rural areas on the outskirts of towns and of rights of way; the Kyrle Society (1877), which was formed for bringing beauty home to the people; and the Metropolitan Public Gardens Association (1882), which takes steps to secure the provision of parks, gardens, playgrounds, gymnasia, the planting of trees and the placing of seats in thoroughfares, &c., within or near populous centres. These bodies have, *inter alia*, obtained the passing of many Acts of Parliament for the protection of commons and open spaces, and for endowing public authorities with powers of acquisition and management in regard thereto. Of more recent date are the London Playing Fields Society (1890) and the National Trust for Places of Historic Interest or Natural Beauty (1894), whose objects are sufficiently indicated by their titles. With this introduction the subject may be divided under certain main heads:—

1. Commons.—Under the Commons Act, 1876 (39 & 40 Vict. c. 56), schemes can be sanctioned by the Inclosure Commissioners (now the Board of Agriculture and Fisheries) embodied in a provisional order and confirmed by Parliament, for the regulation and improvement of commons for use by the public, with due regard to the interests of the lord of the manor and commoners, conservators being appointed to carry out schemes and

exercise general powers of management. This Act, although not absolutely prohibiting the inclosure of common lands (which under the Inclosure Acts, were being rapidly inclosed and divided up all over the country), placed a most desirable check upon this policy by declaring that future inclosures should not be made, unless it were proved to the satisfaction of the Commissioners (now the Board of Agriculture and Fisheries) and of Parliament that such inclosures would be of benefit to the neighbourhood generally, and not merely to private interests. The Law of Commons Amendment Act, 1893 (56 & 57 Vict. c. 57), contains a provision of great importance, rendering it needful to obtain the consent of the Board of Agriculture and Fisheries to any inclosure or approvement of any part of a common purporting to be made under the Statutes of Merton (20 Hen. III. c. 4), and Westminster the Second (13 Edw. I. c. 44). The Local Government Act, 1894 (56 & 57 Vict. c. 73, ss. 8 and 26), confers powers relating to commons on urban, rural, and parish councils. The Commons Act, 1899, marks a further step in advance by simplifying the procedure of the 1876 Act and enabling the Board of Agriculture and Fisheries itself to give full effect to a scheme of regulation without the necessity for obtaining Parliamentary sanction, where no opposition to the scheme is raised by the lord of the manor. It also gives the widest interpretation to the "common" lands, which may be regulated under its provisions. Commons within 25 miles of the City of London boundary and outside the County of London may be acquired and managed by the Corporation of London under the Corporation of London (Open Spaces) Act, 1878 (41 & 42 Vict. c. cxxvii.). Burnham Beeches, Coulsdon, Riddlesdown, Kenley, and West Wickham Commons have thus been secured by the Corporation.

2. Metropolitan Commons.—Under the Metropolitan Commons Acts, 1866 to 1898 (29 & 30 Vict. c. 122; 32 & 33 Vict. c. 107; 41 & 42 Vict. c. 71; 61 & 62 Vict. c. 43), all commons and commonable land wholly or partly within the Metropolitan Police District (the Greater London of the Registrar-General) are specially exempted from inclosure, whether under the Inclosure Acts or otherwise, and schemes can be certified by the Board of Agriculture and Fisheries, with Parliamentary sanction, for the improvement, protection, and management of any such lands in the interests of the public, with due regard to private rights.

3. Parks, Recreation Grounds, Gardens, &c.—The Recreation Grounds Act, 1859 (22 Vict. c. 27), enables land to be conveyed to trustees for public recreation. The Public Improvement Act, 1860 (23 & 24 Vict. c. 30), enables a two-thirds majority of ratepayers of any parish to secure land for public walks and playgrounds. The Public Health Act, 1875 (38 & 39 Vict. c. 55, s. 164), the Public Health Acts Amendment Act, 1890 (53 & 54 Vict. c. 59, ss. 44 and 45), and the further Amendment Act, 1907 (7 Edw. VII. c. 53, ss. 76 and 77), give urban authorities power to acquire and manage public walks and pleasure grounds. These three Acts do not apply to London. The earlier Acts of 1859 and 1860 and the isolated provisions in the Public Health Acts must give place in importance to that comprehensive measure, the Open Spaces Act, 1906 (6 Edw. VII. c. 25), embodying several previous Open Spaces Acts, which gives full powers to local authorities in England, Wales, and Ireland (including London) to acquire and maintain open spaces of various kinds for public recreation. Under the Public Libraries Act, 1892 (55 & 56 Vict. c. 53, s. 13), public spaces are protected from conversion into library building sites; and the London Government Act, 1899 (62 & 63 Vict. c. 14, s. 32), prohibits borough councils from alienating recreation grounds.

4. Squares, Crescents, Ovals, and Similar Inclosures.—It is very necessary to preserve all such areas, whether or not open to the public, as they form valuable oases and breathing spaces in the midst of crowded surroundings and afford grateful relief to the

eye of the passer-by. The Gardens in Town Protection Act, 1863 (26 Vict. c. 13), provides for the protection and upkeep of all such garden inclosures and the levying by the local authority of a special rate on occupiers entitled to use them. The Open Spaces Act, 1906 (6 Edw. VII. c. 25), contains special provisions and procedure for the transfer by trustees and others of such areas to the local authority with a view to their maintenance as public gardens. In London the Metropolitan Public Gardens Association has been able to secure and lay out many such grounds and transfer them to the appropriate authority to maintain for public use. The London Squares and Inclosures (Preservation) Act, 1906 (6 Edw. VII. c. clxxxvii.), marks the very desirable commencement of making such areas, of which 67 are included in its schedule, ineligible for building purposes.

5. Disused Churchyards and Burial Grounds.—Until the year 1884 such areas, at least in towns, were too often allowed to fall into a neglected and insanitary condition, or were quietly sold and transformed into building sites. The Disused Burial Grounds Act, 1884 (47 & 48 Vict. c. 72), as amended by the Open Spaces Act, 1887 (50 & 51 Vict. c. 32, s. 4, and schedule), prohibit building thereon. The Metropolitan Public Gardens Association has taken the lead in rescuing many of these areas from utter neglect and laying them out as bright and pleasant public gardens. The requisite procedure is contained in the Open Spaces Act, 1906 (6 Edw. VII. c. 25). In the Metropolis the London County Council has special powers for enforcing the observance of the Disused Burial Grounds Act, 1884, under the Metropolitan Board of Works Various Powers Act, 1885 (48 & 49 Vict. c. clxvii.).

6. Tree Planting in Thoroughfares.—The planting of trees in roads of suitable width is not only desirable from an hygienic point of view, but the foliage provides grateful shade and welcome relief to the eye in the midst of bricks and mortar. Public authorities outside London are enabled to undertake this work by the Public Health Acts Amendment Act, 1890 (53 & 54 Vict. c. 59, s. 43), and in London by the London County Council General Powers Act, 1904 (4 Edw. VII. c. ccxliv., s. 49). Great care has to be taken in regard to planting, pruning, watering, and maintenance. Irreparable injury is too often done by entrusting such work, especially pruning and lopping, to unskilful and untrained hands. Only certain trees will flourish in the smoke-laden atmosphere of large towns, *e.g.*, planes (*par excellence*), certain varieties of poplar, robinias, catalpas, limes, &c. The purer the air, the greater becomes the choice. Care has to be taken to avoid gas, water, and other pipes. Soil in suitable and adequate quantities must be imported where needful. Useful information on this subject is given by the Metropolitan Public Gardens Association.

7. Laying out and Maintenance of Grounds for Public Use.—It is impossible within the limits of an article to give any detailed directions. The skill and knowledge of a trained landscape gardener is desirable in order to make the most of a ground, with due regard to its size, use, and environment. In the case of commons and heaths the endeavour should be to preserve all natural features and avoid artificiality or elaborate treatment, which not only add greatly to first cost, but involve heavy annual expense for maintenance. Also over laying-out tends to curtail the chief function of a ground as a place to be used for exercise and recreation and not merely to be looked at. The public much prefer to walk and enjoy themselves on grass and under the shade of trees than to be shut out therefrom and confined only to footpaths by the introduction of unnecessary flower-beds and shrubberies. In really small grounds, however, appearance assumes more importance, and greater elaboration is admissible.

8. Rights of Way and Roadside Wastes.—It is the duty of district councils, whether they be highway authorities or not, by the Local Government Act, 1894 (56 & 57 Vict. c. 73), to protect all public rights of way, to prevent obstruction, whether within or

adjacent to their district, and to institute or or defend legal proceedings. District councils can be set in motion by parish councils, and in rural districts an appeal lies to the county council in case of inaction. Under the same Act it is obligatory upon district councils to prevent unlawful encroachments on roadside wastes, which add so much to the appearance of a road and to the pleasure of those using it. As in the case of footpaths, parish councils can put district councils in motion with an appeal to the county council in case of neglect. County councils have power to move independently in the event of encroachments on main roads.

9. Statistics.—In 1883 in the area of the present county of London there were 103 spaces of various kinds available for public use, about 4,000 acres in extent, which gave 1 acre of public space to 950 people. At the present time (1910) in the same area there are 320 spaces, aggregating over 6,000 acres in extent, or 1 acre of public space to 750 people. In 1883, 46 selected cities and towns (excluding London) of the United Kingdom possessed 173 public spaces over 8,000 acres in area, equivalent to 1 acre of public space to 760 people. In the same localities there are now (1910) over 500 public spaces, about 14,000 acres in area, or 1 acre of public space to 640 people.

10. Conclusion.—Great strides have been made during the last 25 years in regard to the provision of open spaces. Public authorities no longer look askance as they once did at proposals brought to their notice by open space societies or private individuals. But the continued existence of societies is none the less necessary in order to be on the watch to take advantage of favourable opportunities, to harmonise conflicting interests, to initiate and put schemes into workable shape, and, it may be, to find part of the money from voluntary sources before bringing them to the notice of one or more public bodies concerned. It has begun to be perceived that open spaces are just as needful for the health and welfare of the community as roads or drainage schemes. Prevention is better than cure, and fresh air and open spaces are better than hospitals. So far the movement has not been systematised, but has proceeded haphazard, and too often the slums of the older part of a town are repeated in the newly-built suburb through lack of forethought. It is therefore very needful, especially in new localities where building proceeds apace, for the local authorities to take time by the forelock and secure open spaces ere too late. Under the Housing, Town Planning, &c., Act, 1909, the need of systematic provision is to some extent recognised, as no town planning scheme will be complete which does not provide for an adequate supply of open spaces. B. H.

Otto Cycle.—(*See* "Gas Engines" and "Oil Engines.")

Outfall Sewers.—(*See* "Sewerage.")

Oxidation of Sewage is effected naturally by atmospheric oxygen, or artificially by oxidising chemicals.

Natural Oxidation.—In this case the gas must first dissolve in the liquid and then must be aided by bacteria, as in sterilised sewage there is little or no action. For the conversion of the carbon and nitrogen of the organic substances into carbonic acid and nitrites or nitrates a large quantity of oxygen is required; thus to nitrify in a sewage five parts of N per 100,000 will demand about half its volume of air, or about 15 volumes of fully aerated water (7 c.c. O per litre) (*see* "Nitrification"). The absorption of a gas by a liquid is hindered by the layer of vapour of the liquid which is constantly forming on the surface. This layer is not affected by currents in the liquid as long as the surface is tranquil, and is only penetrated by gaseous diffusion. Therefore, calm and deep water when deprived of oxygen by bacterial changes is only slowly re-aerated by the atmosphere. The absorption is quickened by winds, and by fountains, cascades and weirs, but Fowler

found at Manchester that "even when air is forced through the liquid for some days the improvement was less than that effected by bacterial filters in eight hours." Several processes of sewage treatment have included forced aeration, but the results do not justify the expense, and a free natural ventilation of filters is sufficient. Green algæ give off oxygen in light and so favour oxidation in waters. One of the chief tests of a sewage or effluent is the amount and the rate of its consumption of oxygen (which is only approximately judged by its permanganate consumption), and the Royal Commission on Sewage have provisionally laid down that after filtration through filter paper, when it must not show more than 3% of suspended solids, it should not absorb more oxygen, dissolved or atmospheric, than, in parts by weight per 100,000, 0·5 in 24 hours, 1·0 in 48 hours, or 1·5 in five days. The Commissioners propose for the determination an apparatus devised by Dr. Adeney, but a simpler method preferred by the writer and others is to completely fill a number of 250 c.c. stoppered bottles with the sewage (diluted if necessary) or effluent, previously saturated by shaking with air, and to determine the dissolved oxygen by a rapid process, such as Rideal and Stewart's modification of Winkler's, *Analyst*, 1901, p. 141, successively in the samples at 12, 24, 48 hours, or longer, at the same time noticing the odour.

Artificial Oxidation.—For this purpose chlorine and ozone are the only practicable agents. Manganese compounds have been tried, but are precluded by expense and for other reasons, and a similar remark applies to peroxide of chlorine (Bergé). (*See* "Nitrification," "Condy's Fluid," "Chloride of Lime," "Electrolysis," and "Ozone.")

S. R.

"**Oxidium**."—An indestructible highly porous mineral substance used as a filtering material between layers of silica in the Candy Compressed Air and Oxidising Waterworks Filters. It possesses properties somewhat similar to those of spongy platinum, and is of volcanic origin. It is treated by a special patent process in order to impart to it the peculiar property of rendering more powerful the oxygen contained in the air with which the water in the filter is first saturated. The atmospheric oxygen is occluded upon the microscopical and interstitial spaces of the "oxidium," and is utilised for the instantaneous oxidation of the iron contained in solution in the water treated by these mechanical filters. The "oxidium" is hard and quite insoluble, and simply acts in conjunction with the oxygen in the air within the filter.

Oxychloride is a chemical preparation produced electrolytically by a company named Oxychlorides, Ltd., and used for the deodorisation of septic tank liquors, &c., as, for example, in cases where the sewage is more offensive than usual through the presence of brewery refuse or other wastes. It has been used at Stone in Staffordshire, and Guildford.

Oxynite.—A precipitant for purifying sewage introduced by the Oxygen Sewage Purification Co., Ltd., which has for its active principle compounds of manganese.

Ozone in Air.—Ordinary oxygen exists as the molecule O_2, but by electric, preferably silent, discharges, or in some slow oxidations, a portion of it is condensed to the molecule O_3; the extra atom of O is called its "active oxygen," since it rapidly oxidises and is removed by sulphuretted hydrogen, sulphurous acid, most metals, and organic substances. Certain tests point to ozone in minute quantity as a normal constituent of the atmosphere; more in sea air than inland, at high than at low levels, and little or none in towns; more after thunderstorms, and least in damp and foggy weather; more in summer than in winter, at night than in daytime, and most at dawn. It is looked for by suspending papers (protected from dust, rain and direct sunlight)

moistened with various solutions. The following is a table of reagents in use and of the effects on them of other possible constituents of air.

	Ozone.	H_2S.	SO_2.	Nitrous.	Cl.	H_2O_2.	NH_3.
1. KI and starch (commonest test)	blue, bleached by excess	—	—	blue	blue	slowly blued	—
2. Faintly reddened litmus and KI[1]	blued, ditto	—	redder	redder	browned	—	blued
3. Wurster's "tetrabase"	blue-violet, ditto	—	—	blue	blue	blue-violet	—
4. Arnold's "tetramethyl-base"	violet, ditto	—	—	yellow	blue	—	—
5. Manganese chloride	brown	slight colour	—	—	brown	—	brown[2]
6. Lead acetate	brown, not delicate	brown to black	—	—	like ozone	like ozone	—
7. Fresh guaiacum tincture	blue, changing colour and bleaching by excess	—	—	blue	blue	slowly blued	—
8. Bright clean silver foil	darkened	darkened	—	—	dulled	—	—

[1] Blued at once by $\frac{1}{261000}$ by weight of ozone, and slightly by 0·0002 to 0·0003 mgm. (See Report on Ventilation of House of Commons, 1906, p. 100; it was concluded that peroxide of hydrogen, and not ozone was present.) Paper dipped in phenolphthalein and KI is reddened by ozone and browned or blued by Cl or nitrous.

[2] It is said that browning due to ammonia is distinguished by not being immediately blued by guaiacum.

Approximate meteorological measurements ("ozonometry") are made by comparison with standard tints produced by known quantities of ozone. Its actual amount may be determined by aspirating a large measured volume of air through a wash-bottle containing permanganate, then through caustic soda, and finally into a solution of pure KI, and titrating the liberated iodine with thiosulphate. Houzeau judged the maximum proportion at ordinary levels to be one volume in several hundred thousand of air. (*See* "Air, Atmospheric, Purity of.") S. R.

Ozone (Purification of Water by).—Ozone is the ideal agent for purifying, since it leaves behind it only ordinary oxygen, and nothing foreign to the water. It was first tried for this purpose by Fröhlich, and Ohlmüller proved that it energetically attacked bacteria in water from which any excess of inert organic matter had been previously removed. These experiments followed the construction of large industrial ozonisers by Siemens & Halske at Berlin, which firm in 1898 erected an experimental plant at Martinikenfelde, and afterwards larger installations for the towns of Wiesbaden and Paderborn. Air ozonised to $2\frac{1}{2}$ to 3 grammes per cubic metre passed upwards through a tower filled with flints, and met a descending current of roughly filtered water. The cost was about $2\frac{3}{4}d.$ per 1,000 gallons of water treated, and a very impure water was sterilised down to 2 to 9 organisms per c.c. Earlier, in 1893, Tindal started his apparatus at Oudshoorn, Holland, and in 1895 worked it experimentally at Paris, also at Brussels and Ostend, and it was adopted for limited supplies at several other places. Leon Gérard estimated the cost at 0·45*d.* per 1,000 gallons. The bacterial reports of Van Ermengem, Marmier, and Roux were satisfactory. Tindal's apparatus attained intimate admixture and duration of contact by passing the water and ozonised air, either in the same or an opposite direction, through towers divided by perforated

diaphragms "or other equivalent dispositions"; another form had pulverisers or spray jets; and the partially exhausted air at the exit could be dried, re-ozonised, and returned. Subsequently, in 1897, appeared the Marmier-Abraham[1] and Otto patents. The former had a mixing tower filled with flints or bricks; the latter injected the water and ozonised air together by means of a pulveriser, called an "emulsor," and later (1905) added a column of flints through which a second current of ozonised air was ascending. These patents are now amalgamated, and are at work on the town supplies of Nice and Chartres, and (experimentally) at St. Maur, Paris. Tindal's previous patent after his death was acquired by De Frise, who has improved the apparatus and process, and has introduced into his plant an ozoniser similar to the Siemens, and an ozone-recuperating circuit. An installation on this principle at the Paris Municipal Waterworks, St. Maur, applied to treating sand-filtered Marne water, which is coloured and bacterially impure, was examined by Rideal in September and October, 1908. He found that the sterilisation was effective and the decolorisation complete without other change, that the working was successful, and that the De Frise process is a satisfactory method of ensuring a standard of purification for a municipal water supply. Miquel's examination in March and April, 1908, had led to a similar conclusion. The total cost of the process would be about 0·33*d.* per 1,000 gallons of water treated, and the actual amount of ozone added at St. Maur was equal to 0·542 gramme of active oxygen per cubic metre (parts per million). This is chemically equivalent to 2·4 parts per million of available chlorine, which was the figure found for tertiary effluent at Guildford. (*See* "CHLORINE PURIFICATION" and "ELECTRICITY.")

S. R.

Pail System.—(*See* "PRIVIES.")

[1] Tried at Lille, 1898, later at Schiedam, and at Moscow in 1901. See also *Electrochem. Ind.*, February, 1903, and *Eclairage Electrique*, December 12, 1903.

Paint-Spraying Machines.—When these appliances were first brought out they were much ridiculed on the ground that it was impossible to apply paint serviceably except by means of the brush; but it has been shown that this is quite a mistake, and in certain cases, notably when the surface is rough, a great deal of saving may be effected by the use of a good paint-spraying machine. If a perfectly smooth and highly finished surface was required, such, for example, as a front door of a private residence, a paint-spraying machine would be useless, but for bridge work, lime-washing, rough brickwork, such as railway arches used for storage, &c., and in many other cases, the paint-spraying machine possesses many advantages over the old-fashioned plan. It will be understood that the paint or lime-wash is forced by means of compressed air from the nozzle of the apparatus into a fine spray, which becomes more diffused the further away the nozzle is held from the surface, but the inequalities and holes are all well covered in a short time, and in a manner which would be impossible if a brush were used. Paint-spraying machines are now made with two nozzles side by side, and by means of their use a surface may be painted or whitewashed in a remarkably short space of time. A. S. J.

Paints and painting.—**General Survey—Washable Distempers—Painting Iron—Removing Paint.**—The municipal engineer usually considers paint chiefly from the point of view of its protective qualities against decay, and not for its decorative value. The base of most paints used for white work is white lead, but on iron work other pigments are generally preferred. The preference for white lead is based upon the fact that this pigment, when ground in linseed oil, possesses the quality known by painters as "body," which means the property of hiding, or masking, the surface to which it is applied. This, however, has really nothing to do with the actual durability of the paint, because one which has little or no body might resist the destroying action of atmospheric conditions, water, chemicals, &c.,

much longer than the white lead. Still, the object in painting is as a rule to obscure the surface, to hide the knots in the grain of wood, and the paint which has the most body effects this object in fewer coats than the one which has less body. For purely protective purposes it is now generally recognised that an admixture of pigments produces the best results, and that, while there is no ideal pigment, or one which possesses the whole of the virtues, yet, where one falls short of perfection, the deficiencies may be made up by adding the proper proportion of another. Generally speaking paint may be said to be composed of either white lead, zinc oxide, or other white pigments, mixed with the necessary colour pigments to produce the desired shade, tint, or hue, or of certain natural earth colours, such as ochre, sienna, oxide of iron, &c. In most cases these pigments are produced in the form of a dry powder, which is ground in a vehicle, almost invariably linseed oil. The durability of such paint depends principally upon, first, the quality of the linseed oil, that is to say, whether it is pure and of the best grade, secondly, upon the degree of fineness to which the pigment is ground, and, thirdly, a thorough admixture of the whole. The fineness of pigments is a point to which much attention has been drawn in recent years, but it is well recognised that within reasonable limits the finer ground the pigment is, the better paint it makes. The question of purity may almost be considered as a side issue; taking white lead as an example, there can be no doubt that exceedingly finely-ground white lead mixed with 25 % of barytes will probably be very much more durable than a pure and coarsely-ground white lead. Painters, as a rule, purchase their white lead or other pigments in the form of a stiff paste, and they then thin it for application by means of a brush by adding a sufficient quantity of linseed oil, either raw or boiled, and American turpentine. The proportion of these "thinners," as they are technically called, depends upon the condition of the surface to which the paint is to be applied. If it is absorbent, such as plaster or open-grained wood, much more oil and turpentine will be required than is the case with iron, which is looked upon as practically non-absorbent, or at least after the first coat. Driers are used to facilitate the absorption of oxygen from the atmosphere, and this quickly affects the drying or hardening of the coat of paint. The proportion of driers used varies largely with the kind of pigment. Vandyke brown and the blacks require a very large proportion of driers, while red lead is in itself a dryer and requires no addition. White lead is also, to some extent, a dryer, and very little additional driers should be employed. The quantity of turpentine is, perhaps, not so important as the other constituents of the paint, because all, or at least the greater part of it evaporates when the paint dries. Still, too much turpentine would render the paint too thin for practical purposes. Only recently, American turpentine was looked upon as a *sine qua non* in all good paint, but the continued high price of the product has caused the paint manufacturer to look very closely into the question, and what is known as "white spirit" in its various forms, frequently mixed with a proportion of American turpentine, is now successfully used as a substitute. White spirit, it may be remarked in passing, is petroleum distilled in such a manner that it has no oily residue, while, at the same time, it does not evaporate so rapidly as to interfere with the manual application. In many cases the municipal engineer will desire to use paint which is simply preservative, quite irrespective of its "body," or covering, and in such a case probably a mixture of white lead and barytes in equal proportions will be as effective as anything. Zinc oxide may also be employed for the same purpose, but the price is slightly higher than white lead, although lower in reality, because it spreads over or covers, when made up into paint, at least 25 % greater surface. Red lead possesses advantages when hard wear and tear has to be resisted, as, for example, in painting barrows, carts, &c. (*See* "RED LEAD.") The protection of ironwork is

obviously of great importance, and there are various special paints made for this purpose. Some engineers consider oxide of iron the best protective paint for iron, while others are just as strongly in favour of red lead. The Tower Bridge was repainted from end to end with white lead only, although this is contrary to the usual practice. There is at this time a strong tendency towards the use of graphite paints, *i.e.*, those made from plumbago ground in oil. The pigment used for this purpose is often mixed with silica and various other materials. Graphite paint is very extensively used in the United States of America, and other places, and it appears to be certain to succeed equally well here when its merits become more widely known. In a table drawn up by Mr. J. Cruikshank Smith which gives the comparative durability of various paints, it is clearly shown that graphite paints are superior to all others when the following points are taken into consideration:—First, the prime cost; second, the average time the paint will last, *i.e.*, the period before repainting will be necessary; third, the spreading capacity—that is the surface a given quantity will cover when made into paint; and fourth, the cost of application. It cannot be too strongly urged that the actual cost of labour in applying a paint is a very material item in determining its economic value. Some authorities place the cost of application at two-thirds, but, even taking it at one-half the cost of the paint, it will be seen that it is by no means economical to use a paint which requires to be frequently renewed. Of late years the subject of painting has been dealt with on a scientific basis, and the old idea that the best paint for all purposes is necessarily a mixture of white lead, linseed oil, and turpentine has been shown to be erroneous, and engineers are recognising the fact that a paint which would be very suitable and cheap for one purpose might be wholly unsuitable for another. It is also becoming recognised that an admixture of pigments, which has already been referred to, is a plan by means of which the best and most economical paint can be obtained, always provided that the thinners are of the proper kind and are used in the right proportions. There is also a tendency towards a departure in another direction, viz., that of varying the constituencies of the several coats of paint. A manufacturer may bring out a special paint produced by a careful study of the requirements of ordinary work, and probably also as a result of an elaborate set of experiments, but he is under the disadvantage that the paint must necessarily be uniform in quality. The painter, on the other hand, can mix each coat of paint for the purpose of which it is to be applied. The painter also varies the quantity of thinners in several coats of paint in such a manner that one coat is rather oily and the next rather "flat." This has the effect of giving a grip, or hold, of one coat upon the other and is productive of good results. In ordinary painting the only difference between the several coats of paint is in the priming coat, which is usually mixed with a small proportion of red lead, in order to give rigidity and firmness to the foundation. With the exception of the proportion of thinners already referred to, the composition of the subsequent coats is almost identical. The very extensive use of enamels in recent years has led to further investigation which shows clearly that not only should the thinners be varied in different coats, but the pigments should be likewise changed. An example may be given in the preparation of ordinary work which has to be finished in white enamel. In this case the primary coat should be white lead with a little liquid dryer of good quality; red lead should be omitted here in case it finds its way through the subsequent coat. The second coat should be also of white lead mixed to an oily finish, and the third coat should be of paint made of white lead and zinc oxide in the proportions of one-half of each. The fourth coat should be pure zinc oxide mixed quite flat, *i.e.*, mixed with turpentine only, without oil, but with a little binder, such as gold size. These four coats should be rubbed down perfectly level, when a white and flat surface will be

obtained, which will give a splendid surface for the white enamel to be afterwards applied, and this will show up to the best advantage. The object of using zinc oxide for the final coat is that it is very white, much whiter than white lead, which is comparatively of a yellowish cast. The final coat of white enamel is, to some extent, transparent, so that if an undercoat of white is given it will show through and give the best results.

Washable Distemper is a modern class of water paint largely used and of great hygienic value. This class of paint is supplied in three forms, in the form of dry powder, in a stiff paste, and in a condition ready for use. Washable distempers are made in a very large number of useful colours and are easy of application. They produce a perfectly flat finish free from gloss. There are not many brands which are really washable, but the best of them, a month or so after application, may be washed down with a fine sponge without injury. For this reason washable distempers are eminently suitable for the walls of churches, hospitals, infirmaries, and public institutions generally. Those parts which are subject to much wear may be protected by giving the distemper a coat of varnish. In most cases it will be necessary to size the distemper before the varnish is applied, and unless this is done the colours of the distemper will be much darkened by the varnish. On occasions this may be an actual advantage, as in the case of a room decorated throughout with a distemper, say, in a series of greens. Very light green could be used on the ceiling, the walls could be a medium shade of the same green, and then a dado, 5 ft. or more high, could be formed with a suitable border on top. By varnishing this dado the distemper will be darkened, and the decorative effect, on the whole, will be good. In many cases engineers prefer to use enamel instead of distemper for the walls of hospitals, on the plea that the surface should be frequently washed down, so as to remove any possible germs or bacteria. It is hardly necessary now to enter into the different aspects of this controversy, but it will be sufficient to say that if the funds admit of a constant washing down of the walls and of the original cost of the enamel, that material is the best for the walls of public institutions. But if, as usually happens, the walls are not actually washed down, except twice a year, then washable distemper, which costs so much less, answers the purpose equally well.

Painting Iron.—The first essential in painting ironwork is to remove every particle of rust, as, unless this is done very thoroughly indeed, the rust will continue to spread underneath the surface of the paint. The means adopted for removing the rust are usually chipping off with a chisel, and thoroughly brushing with stiff wire brushes ; but the job is a long and expensive one, and the writer suggests that there is room for the introduction of a little instrument of hammerlike character, actuated by electric power, which could be also used for scraping. When it is practicable, it is unquestionably cheapest in the end to thoroughly clean the iron by means of a sand blast. This process yields a surface like silver, and, although it is expensive at the start, yet the paint—if a good one—will, upon such a surface, last for years, whilst if it is applied over rust, scale, &c., its life is a very brief one.

Removing Paint.—The old-fashioned plan of removing paint is to burn it off by means of a blow-lamp and scraper. There is objection, however, to the fumes thus given off, particularly when the work is indoors, and also to the liability to burn delicate mouldings, &c., if great care is not taken. There are a number of "paint removers" on the market, the best of which are free from caustic soda, and consist of a substance which does not injure the hands, but which, when brushed on paint, softens it so thoroughly that, after a period of a few minutes to a quarter of an hour, it may be easily wiped off with a piece of waste. Caustic paint removers require the application of an acid, such as vinegar, to kill any of the soda which may be left, but with the new improved paint removers it is not

necessary, and all that is required is, after the paint is taken off, to wipe over the surface with a piece of rag moistened with benzine or turpentine and the work is then ready for immediate painting. A. S. J.

Parks and Pleasure Grounds.—(*See* "Open Spaces.")

Paving.—(*See* "Roads and Streets.")

Penstock.—A penstock is an appliance fitted to the mouth or entrance of a pipe or conduit, as in main drainage works, for the purpose of controlling the flow of liquid through such pipe. The words "penstock" and "valve" are used somewhat loosely in the same connection, but the term "penstock" is more generally applied when dealing with pipes and conduits of large diameter. Numerous varieties of penstocks will be found in the makers' catalogues. A typical form of such appliance, suitable for an egg-shaped sewer, is provided with counter-balance weights and a rack and worm arrangement to facilitate opening and closing. To avoid corrosion, to give a more perfect and watertight fit, and to produce ease of working, penstocks are frequently fitted with gun-metal working faces and worm, and all bearings bushed with gun-metal.

Percolating Beds.—(*See* "Sewage Disposal.")

Pipe Joints, Stoneware.—The joint commonly made use of for stoneware pipes is the ordinary spigot and socket joint, which in most cases answers admirably if well made with neat cement. Care must be taken that the pipes when joined are concentric and that the whole of the socket is well filled, leaving no interstices for the accumulation of sewage matter nor ridges to obstruct the flow through the drain. With the object of facilitating the making of a concentric joint, pipes are frequently tapered at the spigot or provided with excrescences in the socket which answer well if the pipes are carefully made and burned. Some makers (as in the Stanford joint) provide a ring of plastic composition round the spigot and in the socket, which answers the same purpose and which is capable of making a joint in itself if greased with a mixture of tallow and rosin. Such a joint cannot entirely be relied on, and should be used only in conjunction with a cement joint. In other cases, such as Hassall's joint, similar bands are so arranged that when the pipes are put together a mould is formed in the interior of the socket which, when filled with liquid cement through a hole in the wall of the socket, forms a reliable joint.

Pipes, Weights and Dimensions of Cast-iron, for various purposes:—

Light (Waste and Vent Pipes).

Diameter of pipe in inches.	Thickness of pipe in inches.	Length of pipe in feet.	Diameter of socket in inches.	Length of socket in inches.	Weight of pipe in lb.
2	3/16	6.0	3⅛	2½	26.0
2½	3/16	6.0	3⅝	2½	28.0
3	3/16	6.0	4	3	36.0
3½	3/16	6.0	4½	3	40.0
4	3/16	6.0	5⅛	3⅝	46.0
4½	3/16	6.0	5⅝	4¼	54.0
5	3/16	6.0	6⅛	4½	60.0

Medium (Soil and Waste Pipes).

Diameter of pipe in inches.	Thickness of pipe in inches.	Length of pipe in feet.	Diameter of socket in inches.	Length of socket in inches.	Weight of pipe in lb.
2	¼	6.0	3¼	2¾	34.0
3	¼	6.0	4¼	3¼	48.0
3½	¼	6.0	4¾	3⅜	54.0
4	¼	6.0	5¼	4	60.0
4½	¼	6.0	5¾	4	70.0
5	¼	6.0	6¼	4¾	80.0
6	¼	6.0	7¼	4¾	98.0

Heavy (Soil and Drain Pipes).

Diameter of pipe in inches.	Thickness of pipe in inches.	Length of pipe in feet.	Diameter of socket in inches.	Length of socket in inches.	Weight of pipe in lb.
3	⅜	6.0	4½	3⅜	7.00
3½	⅜	6.0	5	3½	8.00
4	⅜	6.0	5½	3¾	9.00
4½	⅜	6.0	6⅛	3¾	118.0
5	⅜	6.0	6½	4	130.0
6	⅜	6.0	7¾	4	150.0

CAMERON AND ROBERTSON.

SPIGOT AND SOCKET PIPES FOR WATERWORKS FOR 300 FT. WORKING HEAD. TESTED TO 600 FT.

Bore.	Thickness of Metal.	Length exclusive of socket.	Average Weight per Pipe.		
Inches.	Inches.	Feet.	Cwt.	Qrs.	Lbs.
2	$\frac{3}{8}$	6	—	2	4
$2\frac{1}{2}$	$\frac{3}{8}$	9	1	0	0
3	$\frac{3}{8}$	9	1	0	10
4	$\frac{1}{2}$	9	2	0	0
5	$\frac{1}{2}$	9	2	1	7
6	$\frac{1}{2}$	9	2	3	14
7	$\frac{1}{2}$	9	3	1	0
8	$\frac{1}{2}$	9	3	2	23
9	$\frac{9}{16}$	9	4	2	24
10	$\frac{9}{16}$	9	5	0	16
12	$\frac{5}{8}$	9	6	3	13
15	$\frac{11}{16}$	9	9	2	3
18	$\frac{13}{16}$	9	13	1	12
24	1	9	28	1	23

Pipes, Weights and Dimensions of Stoneware :—

Diameter of pipe in inches.	Thickness of pipe in inches.	Length of pipe in feet.	Depth of socket in inches.	Diameter of socket in inches.	Weight of 2-ft. pipe in lbs.
3	$\frac{1}{2}$	2	$1\frac{1}{2}$	$4\frac{1}{2}$	12
4	$\frac{1}{2}$	2	$1\frac{1}{2}$	$5\frac{1}{2}$	17
5	$\frac{5}{8}$	2	$1\frac{5}{8}$	$6\frac{7}{8}$	22
6	$\frac{11}{16}$	2	$1\frac{3}{4}$	8	33
9	$\frac{3}{4}$	2	2	$11\frac{1}{4}$	50
12	1	2	2	15	85
15	$1\frac{1}{8}$	2 to 3	$2\frac{1}{4}$	$18\frac{3}{8}$	124
18	$1\frac{1}{4}$	2 to 3	$2\frac{1}{2}$	$21\frac{3}{4}$	190

Plenum System.—A system of ventilation, the principle of which is to force fresh air into a room and draw the vitiated air out by mechanical means.

Plumbing.— Plumbing (Internal) — Buried Pipes—Materials for Water Pipes and Fittings for Soil, Waste and Ventilation Pipes—Cisterns—Ball-valves — Overflows—Stop and Bib-cocks—Joints for Lead Pipes—Joints for Connecting Lead to Iron or Stoneware—Fixing of Pipes—Sanitary Appliances and Trapping—Unsealing of Traps—Anti-siphon Pipes—Puff Pipes — Soil Pipes — Waste Pipes—Water-Waste Preventers—Flush Pipes.

INTERNAL PLUMBING. — That plumbing, particularly in connection with water supply and sanitation, has a considerable influence upon health is now well understood. Whereas, until recently, so-called sanitary appliances were frequently placed in obscure and badly lighted positions, it is now universally demanded that pipes and fitments should be easily accessible and sanitary appliances placed in well-lighted and ventilated positions and concentrated as far as possible. The practice of allowing water service, soil, and waste pipes to be buried in walls, laid under floors, or in other "out of sight" positions, is objectionable and frequently attended with danger. Leakages, burst pipes, &c., not only cause unnecessary damage, but incur much cutting away and making good; moreover, chisels, nails, &c., are often accidentally driven into such pipes, which, in the case of soil or ventilation pipes, may remain undiscovered for some time, meanwhile being a menace to the health of the occupants. Of sanitary appliances, the present demand is for fittings with a minimum of mechanism and fouling surface, and such that the whole may be easily cleansed. It is as well to point out, however, that unless such fittings are placed in positions wherein the surrounds are both visible and accessible, it is doubtful whether the absence of an inclosure is advantageous. Plumbing, to be carried out in a proper manner, requires skilled craftsmanship and attention to a number of details, as will be more readily understood from the following :—

ESSENTIAL CONDITIONS AND DETAILS OF PLUMBING : SELECTION OF MATERIALS.—The characteristic of the water supply should be considered. Most soft waters have a solvent action on lead and zinc, rendering the use of these metals dangerous. Iron is also affected by soft water to such an extent that discoloration of baths, lavatories, and domestic utensils follows, as well as corrosion of the pipes, &c. Tin is the best metal for use with such water, tin-lined iron and lead pipes being extensively used for this purpose. For large pipes, iron coated with Dr. Angus Smith's solution is satisfactory; for hot water supply, copper should be used throughout. Practically

any metal may be used for hard water, the calcium carbonates of which quickly coat the pipes, effectually preventing any solvent action. The selection of materials for soil, waste, and ventilation pipes is influenced by cost, exposure to damage and theft, expansion and contraction likely to arise, either from solar heat or by the passage of liquids through the pipes. Brass-work and other fittings should be of good quality, remembering the adage "the cheapest is the best of its kind."

Pipes.—All pipes should be placed in accessible positions, and as far as possible where unaffected by frost; where exposure is unavoidable they should be protected by an efficient covering; water services should be so arranged as to enable the whole of the pipes to be easily emptied during severe weather or when the premises are unoccupied. All pipes should be well supported and bends made to an easy radius. In the case of hot-water pipes adequate allowance should be provided for expansion, and when necessary to pass through walls or floors sleeves should be provided. Lead pipes should not be placed in contact with lime or cement, nor should any metal pipe be laid in ground composed of ashes or similar refuse without being surrounded with a suitable protective material. All pipes should rise to allow air to automatically pass out, either through the cistern or some fitting such as a ball-valve or tap, or, in the case of a hot-water apparatus, the expansion or open pipe. Underground pipes should be kept about 2 ft. 6 in. below the surface to prevent the water freezing.

Cisterns.—Cisterns should be placed in well-lighted, ventilated, and warm positions, and be provided with covers. Although the water for dietetic purposes should be drawn direct from the main, cisterns are necessary for the hot-water supply[1] and to provide storage for sanitary appliances. The absence of cisterns in the latter case occasions much discomfort should the public supply be turned off for repairs, &c. Lead or other safes should always be provided under cisterns placed over ceilings and where a leakage would cause damage; condensation on the sides of cisterns and pipes often gives rise to a supposed leakage. Owing to the affinity of water for gases, cisterns and also the overflows therefrom should not be placed near the ends of soil, waste, or ventilation pipes, or in any position where impure air may have access.

[1] In Canada and some parts of the United States of America the cold water supply is connected direct from the main to the hot-water apparatus.

Ball-Valves.—Ball-valves should be properly fixed, either to the top of the cistern or the wall immediately above, or passed through the side of cistern and made secure with a back-nut. Confusion often results from the terms "high" and "low" pressure ball-valves. A ball-valve with a restricted orifice exposes a smaller area to the pressure of water within the pipe than a full-bore valve, the sum of the moments required to ensure the valve closing being proportionately less. Briefly, a "high-pressure" ball-valve has a restricted orifice, a "low-pressure" being full-way or full-bore. Ball-valves of the full-bore type, in which the moments are increased by compound levers and also those of the "equilibrium" pattern are obtainable; in the latter, the water presses on each side of the piston or jumper. These valves are used on both high and low pressures.

Overflows.—Overflows should be large enough to take away the water when the valve is full open. The diameter should bear some proportion to the size of the supply pipe and the pressure therein, and should in all cases be at least 50% larger in diameter than the inlet. It is a common occurrence for ball-valves to become fixed, especially during the emptying of cisterns; it is also frequently found that the ball is filled with water, when it fails, of course, to float; a further risk is that of the ball becoming detached from the lever. In each instance the valve may remain full open, and, failing the provision of an adequate overflow, result in much damage. It is necessary to protect the ends of large overflows to prevent birds building therein. Valves when fixed on the ends of overflows should be

light and work freely to avoid obstruction or failure to open at the desired moment.

STOP- AND BIB-COCKS.—Stop and bib-cocks of the screw-down type are generally insisted upon by the various water authorities; by their use the risk of breakage of pipes by shock or the setting up of water-hammer (a chattering of ball-valves) is reduced. Such valves are also more easily repaired and are more economical in use than plug valves, although the latter are largely used and preferred in many establishments owing to the water issuing full-bore by giving the handle a half-turn. Quick-turn screw-down valves are frequently fitted to lavatory basins, the spindle being screwed to a quicker pitch, these valves are preferred on the same grounds as plug valves. Spring or cam-action valves are also frequently used for lavatory basins, mainly to prevent waste of water; they are more liable to get out of order and more difficult to repair. Stop-cocks should be fitted to all services—on the main pipe before or immediately it enters the premises, and on down services as close to the cistern as possible. In the latter case they should be labelled with the fittings controlled. Full-way, or, as they are also termed, Gate or Peet's valves offer the least obstruction to the passage of water. Very often such valves do not close so tight as the ordinary pattern "screw-down" valve. For use on lead pipes many prefer to use stop-cocks with unions thereby facilitating the taking out of the body of the valve should necessity arise, and also to prevent the body of the valve being heated during soldering. When such stop-cocks are placed underground there is a risk of leakage at the unions; for this reason "tinned-end" stop-cocks are often preferred. Stop-cocks should be fixed on all important branches, and wherever repairs would cause inconvenience by the shutting off of water to other parts of the premises. Bib-cocks should be securely fixed, and in the case of sinks at a sufficient height to pass a pail under, the usual height being 14 in.

JOINTS FOR LEAD PIPES.—The only permissible joint for lead pipes, unless used for acids, is the wiped soldered joint. In all wiped joints to lead pipes the preparation consists of forming a socket and spigot, care being taken that the bore is not obstructed and that the spigot points in the direction of flow, thus avoiding an edge for the water to impinge against. The pipe for a few inches on each side of the joint is coated with "soil"—a mixture of vegetable black and size or glue—to prevent solder adhering to the pipe; that portion of the pipe to be soldered is then "shaved" bright and "fluxed." After the pipe has been sufficiently warmed and a body of solder at a suitable temperature is attached to the joint, the plumber shapes and completes the joint with the aid of a cloth (made of a number of thicknesses of moleskin cloth). Should the joint be in a difficult position or of a large size the solder is kept warmed up whilst wiping by the aid of a "plumbing iron" heated to a dull redness.

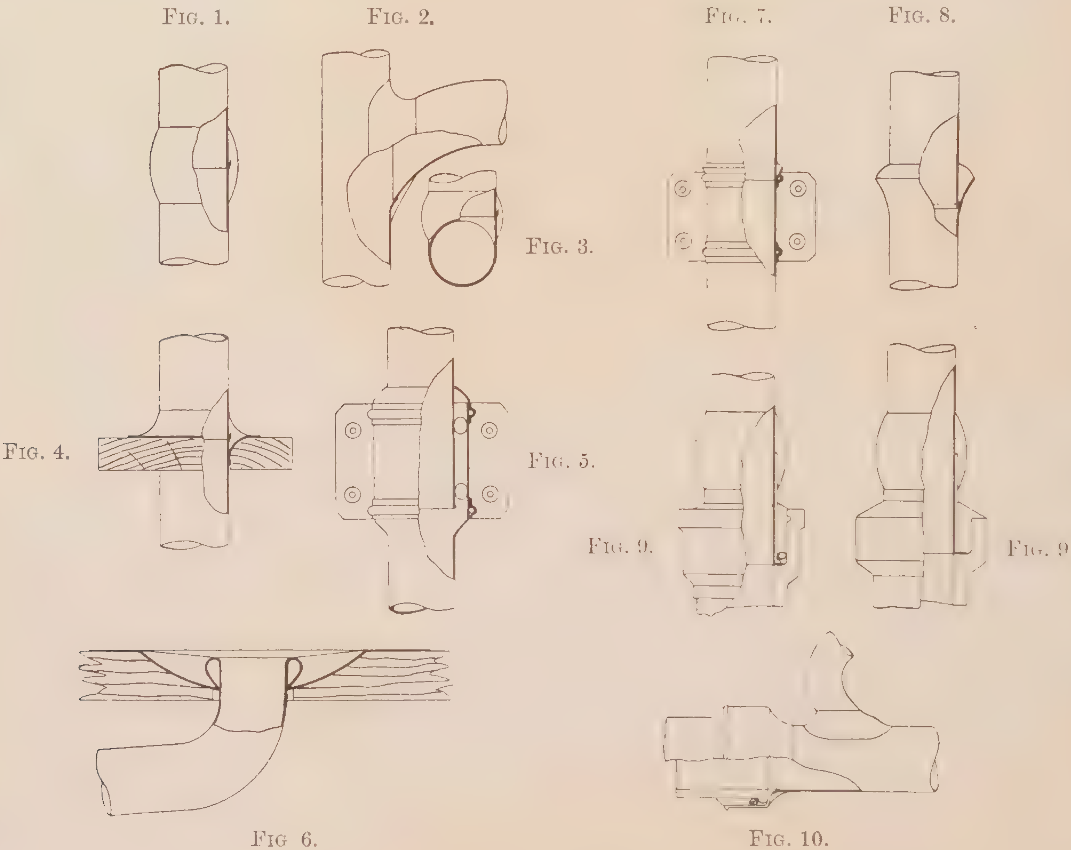
LENGTH OF WIPED JOINTS AND SOLDER REQUIRED.—The length of joints varies in different localities and with different workmen. In London the lengths are approximately as follows:—

$\frac{1}{2}$ in. pipe	3 in.
$\frac{3}{4}$ in. to 3 in. . . .	$3\frac{1}{4}$ in.
$3\frac{1}{2}$ in. upwards . . .	$3\frac{1}{2}$ in.

There is no exact rule for calculating the quantity of solder required for wiped joints; this depends largely upon the preparation; moreover, workmen vary very much in the quantity of solder left on joints; much is also unavoidably lost during heating and use. A fair estimate for general work is to allow 1 lb. per inch bore of pipe; thus for a 2 in. pipe allow 2 lbs., for a 3 in. 3 lbs., and so on. Obviously a heavier joint is required on pipes to withstand high pressure than is the case with soil and waste pipes.

DETAILS OF SOLDERED JOINTS.—Fig. 1 shows a wiped soldered joint as made for connecting up lengths or runs of pipe; such joints are termed "running joints." These

joints may be made in any position; when sufficiently horizontal to enable the solder to be poured thereon from a ladle, they are said to be made "underhand." Where this is not possible or convenient owing to the pipe being in a vertical position, the solder is splashed on and the joint is said to be made "upright." body of the pipe; the ends of the pipe to be soldered should be tinned before being put together. Similar joints are made to lead pipes when passing through lead flats, safes, &c., the leadwork of which takes the place of the lead collar. The taft or block joint is not so reliable as the ordinary wiped joint, as



Soldered Joints.

1. Wiped "Running Joint." 2. Branch Joint. 3. Cross Section of Branch Joint. 4. Taft or Block Joint. 5. Expansion Joint for External Waste Pipes. 6. Outlet Joint. 7. Astragal Joint. 8. Copper Bit or Blown Joint. 9. Joint Connecting Lead to Iron Drain; also Stoneware Drain. 10. Gun Metal Thimble and Joint to W.C.

Figs. 2 and 3 show a soldered branch joint; an important detail is the working up of the sides of the main pipe until they stand up about $\frac{3}{8}$ in. above the top of the same to form a socket for the branch pipe. Fig. 4 shows a taft or block joint; such joints are frequently used on pipes fixed in chases. The socket pipe should stand up well above the lead collar to permit of solder adhering to the Fig. 1, since it is possible for the joint to present a good appearance, whereas the solder may not be properly attached to the pipe. For this reason, ordinary wiped joints are often advocated, blocks and collars being provided between the joints for the purpose of support. Fig. 5 shows an expansion joint for external lead waste pipes. (Whenever lead waste pipes are fixed with rigid joints and hot

and cold water alternately passes through, fracture will sooner or later occur.) These expansion joints are prepared by driving in a mandril to swell out the pipe to form a socket of the required size, the other end of the length is opened to slide freely in the

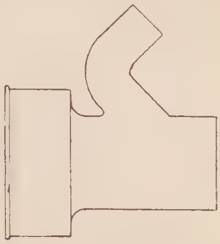


FIG. 11.—Gun Metal Thimble with Anti-Siphon Branch.

socket of the lower length, and to ensure a proper alignment, a bead may be turned for the same purpose. The pipes on which these joints are made should not exceed 6 ft. in length, as obviously the fixings should be at the top end only; such fixings usually take the form of lead tacks strongly soldered to the back of the socket. Ornamental beads (astragals) are often soldered on the socket to improve the appearance. Prior to fixing the

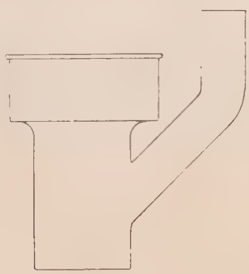


FIG. 12.—Gun Metal Thimble with Anti-Siphon Arm for "Turn Down" Closets.

pipes, india-rubber rings are slipped on the spigot. It is important that sufficient room be left between the end of pipe and bottom of socket for expansion. Fig. 6 shows the form of joint for overflow and outlet pipes to cesspools, &c., a sinking being made in the woodwork into which the lead is dressed; a bead is turned on the end of the pipe and the whole soldered together. Fig. 7 shows an astragal joint as frequently made on lead soil and ventilation pipes. These joints are not so strong as ordinary soldered joints; they are made with fine or copper bit solder, the actual joint being similar to a copper bit joint. As such joints are generally made in position, a blow-lamp is employed, and much care has to be exercised to prevent fusing of the pipe or loosening of the solder holding the mouldings or astragals. The only point in favour of such joints is that the appearance resembles the sockets of rain-water pipes. Fig. 8 shows a copper bit or blown joint as employed on lead and composition gas pipes, and on the cheapest of so-called plumbing. Fig. 9 shows a form of joint for connecting lead to iron or stoneware, the bore of the thimble or sleeve being equal to the external diameter of the lead pipe. Fig. 10 shows a *thimble as connected to a P trap of a pedestal closet.* These short thimbles permit the anti-siphon pipe to be connected near the head of the trap. Fig. 11 shows a *thimble with anti-siphon branch cast on*, and insures the same being connected close to the head of trap. Fig. 12 shows a thimble for use with pedestal closets provided with turn-down or S traps. An advantage of these thimbles is that the joint of the anti-siphon pipe is stronger than when simply socketed into the out-go of trap, and also enables the pan and trap to be removed without interfering with the anti-siphon pipe—an important feature when a pan has to be replaced. These thimbles also insure the anti-siphon pipe being connected on the leg, and not on the crown of the trap, where it would be liable to become choked.

FIXINGS FOR LEAD PIPES.—Lead pipes may be fixed by any of the following methods: Lead tacks, as shown in Fig. 13. These tacks consist of stout sheet lead, or they may be cast of any desired shape; when of sheet lead they are usually made of twice the width, being then turned back over the hooks or nails. The essential points are: that the tacks should be stout—equal to, say, 10 lbs. lead—and of a good length to enable the pipe

to be well supported, but which also depends upon a good width and body of solder adhering to the pipe and tack; for this reason the tack

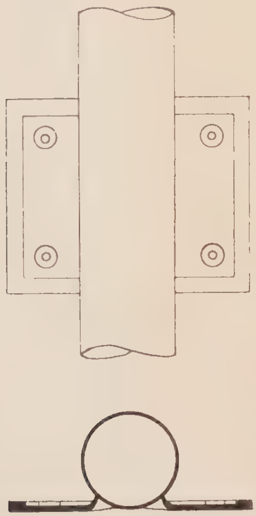


FIG. 13.—Lead Tack.

requires to be well bent up or bevelled close to the pipe. On soil pipes and the like the tacks present a better appearance when fixed in pairs, 5 ft. apart. The tacks described are

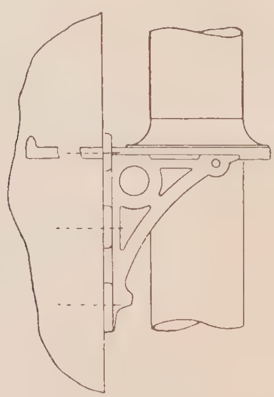


FIG. 14.—Cast-Iron Bracket supporting Lead Soil Pipe.

known as "back tacks." When tacks are soldered on the front they are known as "face tacks," and are held by many to be the stronger of the two; face tacks are largely used for service pipes. Cast-iron brackets: soil, ventilation, and waste pipes are sometimes fixed by passing them through a cast-iron bracket, as shown in Fig. 14, a lead collar being wiped on as described in taft or block joints. Service pipes are frequently fixed with pipe and wall hooks; these hooks should be strong and a piece of sheet lead placed behind the tang to prevent injury

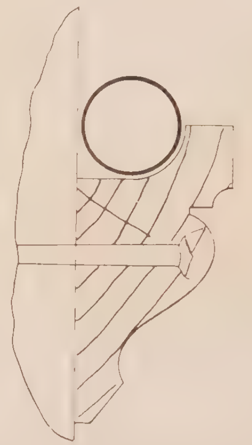


FIG. 15.—Lead Pipe supported on Wooden Fillet.

to the pipe. It is important that horizontal pipes be well supported to prevent sagging and ultimate breakage. Where possible, horizontal lead pipes are best supported on fillets, as shown in Fig. 15.

SANITARY APPLIANCES AND TRAPPING. — All sanitary appliances should be trapped as close to the fitting as possible, and all such traps should be of a material which lends itself to sound jointing; they should also possess a smooth interior, sufficiency of water seal, and the shape should be such as to resist siphonage by momentum. In addition, the inlets of all traps should be at least equal to the sectional area of the water in the trap, the body of which should be contracted to hold a minimum quantity of water compatible with efficiency. The outlets to baths, sinks, lavatories, and similar fitments should be of a size equal or larger than the trap, and possess a clear way. Traps of the round pipe, or those of the anti-D shape, are alone permissible

for sanitary appliances. Lead traps possess a smooth interior, and are easily jointed to the fittings and waste. Traps of cast iron and brass are also used on sanitary appliances, and care should be taken to insure that the same have a smooth interior. The best forms are vitreous or glass enamelled inside; the ends may be screwed for connecting to iron or other materials, or provided with a union for soldering to lead.

Loss of Water Seal.—Traps may be rendered futile by (*a*) evaporation of the contained water; (*b*) momentum, as when the momentum of the water passing through the trap is so great as to leave an insufficiency of water to re-seal the trap; (*c*) siphonage, caused by unequal atmospheric pressure on the surfaces of the water in trap, which may be caused when water passes down an unventilated soil or waste pipe, the falling water tending to leave a vacuum behind, or when a discharge of water passes by an unventilated branch pipe, pulling some of the air with it; (*d*) waving out or oscillation, caused by alternations of pressure on the surface of water in out-go of trap, imparting a waving motion to the water therein, a small quantity passing over the weir at each oscillation. This action may be caused by a "blow-down," or by the discharge from a distant fitting compressing the air in the branch to which the trap is connected; (*e*) capillarity, as when pieces of cloth, hair, or other fibrous material lodge on the weir of trap; water passes up such matters as oil up a lamp-wick, the seal being ultimately destroyed. Traps may also be unsealed by compression of gases, as when storm water rises in sewers, or when the temperature of air in unventilated pipes is raised.

Anti-siphon Pipes.—These are pipes fixed to prevent loss of water seal in traps, and to ventilate the branch pipes. To be effective they should be connected within 3 in. to 12 in. of the head of the trap; if connected nearer the head there is danger of matters washing up the same, if connected at any distance further than 12 in. from the head the pipe may not properly prevent siphonage. The diameter of the pipe should not be less than $1\frac{1}{4}$ in. in the case of waste pipes, nor less than 2 in. in the case of soil pipes. Where there is a probability of the waste or soil pipe being fully charged with water it is best to increase the size of the anti-siphon pipes; in fact, with baths fitted with full-way wastes the anti-siphon pipe would be better if of the same diameter as the waste. Where a number of anti-siphon pipes are connected together, the diameter of the main pipe should be increased.

Puff-Pipes.—These are anti-siphon pipes which terminate on the face of the wall instead of being carried up to the roof level or branched into the main stack; obviously puff-pipes, if used at all, should only be used in connection with waste pipes; where such pipes are used, care should be taken that the open end is well away from windows, &c. Practically speaking, puff-pipes are objectionable, and are only used where the expense of carrying a pipe up to above roof level is considered too great. The pipe between the valve and trap in valve-closets is also termed a puff-pipe, and also the pipe between the traps of some makes of siphonic closets; in each case they should terminate on the face of the wall.

Soil Pipes.—Materials for soil and ventilation pipes are practically confined to lead and iron. Zinc and sheet-iron pipes should not be permitted, owing to the rapid corrosion of these materials when in the presence of moisture and drainage gases. Drawn lead pipe of a substance equal to 7 lbs. lead, and iron $\frac{3}{16}$ in. to $\frac{1}{4}$ in. thick, practically form the basis of the L. C. C. by-law respecting soil pipes.

Lead Soil Pipes.—Lead pipes 2 in. and upwards are usually made in 10 ft. lengths, and may be obtained of any substance up to 10 lbs. lead. Although 7 lbs. lead is practically the minimum substance allowed by the L. C. C., 8 lbs. is to be preferred; whilst 10 lbs. is frequently fixed. Lead is for all practical purposes the best material for soil and venti-

lation pipes. Amongst its advantages are: the ease with which it may be bent and fitted to any position, smoothness, few and sound joints, and, when properly ventilated, immunity from corrosion. Owing to possible damage by solar rays, a position sheltered from the sun should, if possible, be selected. Lead cannot be advocated for soil pipes through

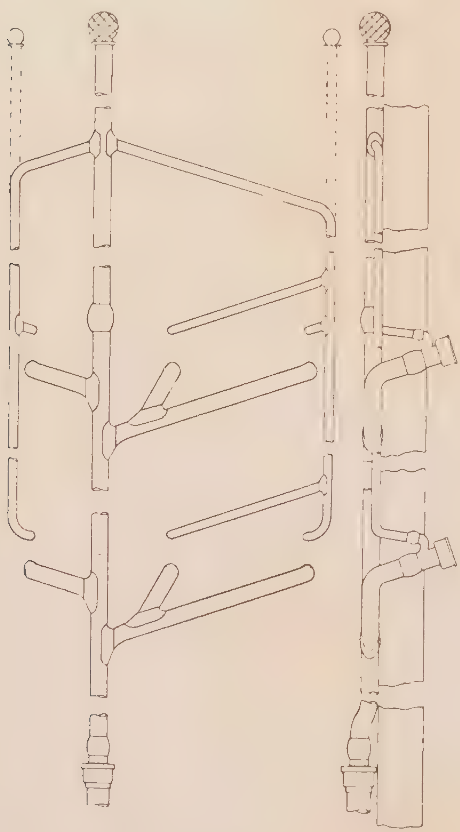


Fig. 16.—Arrangement of Soil and Ventilation Pipes.

which hot and cold water, as from slop-sinks, is alternately passing, unless some form of expansion joint is used. Fig. 16 shows the arrangement of soil, branch, and ventilation pipes suitable for various conditions. The termination of anti-siphon pipe may be branched into the soil pipe a few feet above the top closet or branch, or may be carried up to the same height as the soil pipe. When the top of the soil pipe is some considerable distance beyond the top branch, air may more easily—owing to reduced friction—reach the branch to which the trap is connected, if the end of the same is branched into the soil pipe instead of carrying up a separate pipe. The open ends of soil pipes should be placed well away from windows, or any opening to the house, and be carried well above the eaves of the roof. Owing to the affinity of water for gases, care should be taken to insure the ends being well away from cisterns. As air should be able to pass down soil pipes whenever a fitting thereon is flushed, air-extracting cowls should not be placed on the ends. (Details of joints and methods of fixing pipes will be found under their respective heads.)

Iron Soil Pipes.—Iron, on account of cheapness and hardness of material, is largely used for soil and ventilation pipes; the pipes should be of good substance, approximately $\frac{1}{4}$ in. thick, be well protected from corrosion, and the sockets made deep, and with a sufficient annular space for caulking. All iron pipes are best fixed clear of the wall, either on "holderbats" or brackets. The joints are best made with molten lead properly caulked. It is best to dispense with the use of yarn, using lead rope or lead wool instead. The interior of the pipes should be examined for obstructions and smoothness. When cast-iron soil pipes are used it is usual to connect the closet to the same by a brass or gun-metal thimble wiped on to a piece of drawn-lead pipe, such being compulsory in the L. C. C. area. Iron is not a commendable material for ventilation pipes, owing to the accumulation of rust at the base of the pipe; for this reason lead is preferred by most sanitary engineers. Care should be taken in cutting iron pipes to insure a true cut; the best tool for this purpose being "wheel cutters" of the Jones's type. Such a tool also effects a saving of time.

Waste Pipes.—The practice of discharging waste pipes over hopper heads and over the tops of gulley gratings is offensive and objectionable; the aim in all cases should be to permit the waste waters to enter and pass

through the gulley and thence through the drain with the minimum of obstruction and splashing. With this object modern practice is to construct the waste pipes and stacks thereof similar to soil pipes, except that the lower end discharges under the grating, but over the water of a gulley trap; the main stack being usually 2 in. to 3 in. diameter. With a single fitting on the ground floor it is more usual to omit the stack and carry a puff-

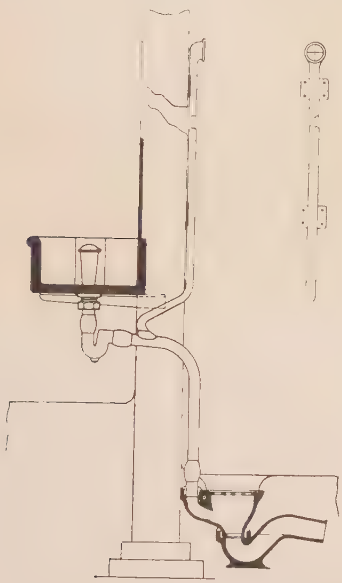


FIG. 17.—Sink with Trapped and Ventilated Waste discharging into Back Inlet Gulley.

pipe up about 7 ft. high (*see* PUFF-PIPES); care should be taken to insure the puff-pipe terminating in a position above the top of the fitting to which it is connected, or it may act as an overflow in case of stoppage of the waste pipe. Although the use of puff-pipes is better than hopper heads, neither are so good as carrying the pipe up in the manner described. The size of waste pipes varies somewhat, but in no case should they be less than $1\frac{1}{4}$ in. diameter. The sizes recommended being: Lavatories, $1\frac{1}{4}$ in. to $1\frac{1}{2}$ in.; baths and sinks, $1\frac{1}{2}$ in. to 2 in. Lead, as in the case of soil pipes, is the best material for general use; where a large quantity of hot water passes through and the pipes may be fixed outside, expansion joints as described under "Joints" should be used; if the pipe must of necessity be fixed inside, it would be best to use copper or wrought iron properly protected, the lengths being connected with screwed sockets; suitable fittings for connecting branches may be obtained. Cast iron with socketed joints is also largely used for waste pipes; they should be smooth and properly protected, preferably glass or vitreous lined. Fig. 17 shows sink waste pipe fitted in the manner above described.

WATER-WASTE PREVENTERS. — Water-waste preventing cisterns of innumerable designs are obtainable. The most reliable form, so far as flushing is concerned, are those in which a flush may be obtained whether the lever be held or released, such cisterns being those provided with a valve and siphon; the holding up of the valve permits the water to pass down the flush pipe, setting up siphonic action, thus insuring a flush whenever there is any water in the cistern. Many water authorities object to this type of cistern on the ground that a leakage past the valve is possible. In all cases the cistern should fill in 60 seconds, or thereabouts; to ensure this $\frac{3}{4}$ in. full-way ball-valves should be fitted to cisterns under 10 ft. head of water.

FLUSH PIPES.—These may be $1\frac{1}{4}$ in. to $1\frac{1}{2}$ in. diameter; care should be taken to obtain a sound joint to the arm of the w.c. pan; indiarubber cones are unreliable, a better form being the lead cones, which may be bossed up by the plumber or purchased ready made.

To reduce the noise during the filling of the cistern a tube should be attached to the ball-valve and carried down to near the bottom of the cistern, thus submerging the end. The gurgling noise consequent upon the emptying of the cistern and the inrush of air may be minimised by a valve arrangement, which opens during the emptying of the cistern, allowing air to enter and check the siphonic action before the cistern is finally emptied. Flushing cisterns fixed just above the seat reduce the noise consequent upon emptying; such cisterns are specially made for the purpose, and have a larger outlet

to compensate for the lower head. Flushing cisterns are sometimes dispensed with and the closet flushed by a valve, which permits a predetermined quantity of water to pass at each flush, somewhat similar to the flushing arrangement of many valve-closets. The size of the supply pipe to these valves depends upon the head of water above the closet. Cisterns for soft water are often made of wood and lead-lined, brass fittings being used. Glass-lined iron is satisfactory providing the coating is properly applied. Glazed fireclay cisterns are also used, but as fireclay is of a porous nature the soundness of the cistern depends upon the glaze, and should the same be chipped beneath the water line and there be any defect or chipping on the outside, a leakage would result. The writer has had to replace a number of fireclay closets for a similar reason and because of the under side of the flushing rim being unglazed, in which case the water enters the fireclay and oozes through any unglazed part, frequently the screw holes and under the pan. W. F.

Plumbing (External).—**Sheet Lead—Weights of Lead—Lead Rain-water Heads and Spouting—Lead-burning —Soakers — Step-flashing—Hip and Valley Soakers—Secret Gutters—Roof Lights—Dormers—Gutters and Flats—Roof Cesspools and Shoots—Covering Stone Cornices.**

Plumbing (External).—Externally, the principal work of the plumber is to cover and protect the woodwork of roofs, the lining of gutters, rendering watertight the junctions of walls, chimneys, &c., to roofs, covering of cornices, &c. Sheet lead is mainly employed for such purposes; this on account of its durability and the ease with which it may be "bossed" or worked to fit various positions or to take the shape of the woodwork or other material it is to cover. The life of sheet lead depends largely upon the surface of the material on which it is placed and the manner in which it is laid or fixed; hence it is important that all woodwork should be substantial and seasoned, the boards of narrow widths and laid in direction of fall; all joints should be properly flushed and any angles rounded. Flats, gutters, and the like should not be arranged with sharp falls, owing to the tendency of lead to "creep" (in specially steep situations, as on hips, turrets, &c., the lead may be easily fixed to prevent creeping), nor should the fall be less than 1 in. in 10 ft. To prevent fracture from atmospheric changes, sheet lead should always be laid in as free a manner as possible consistent with security; solder, except to cesspools and outlet pipes, should not be used, but the lead evenly and properly bossed to the desired shape. The pieces should not be of excessive size, and nothing longer than 10 ft. permitted; if possible, a length approximating to 7 ft. would be more durable. Drips, laps, and passings should be deep or long enough to prevent water passing between the sheets by capillary attraction. The weights of lead suitable for various purposes are as under:

Soakers . . 3 lbs. to 4 lbs. per square foot.

Stepped flashings .	5 lbs. to 7 lbs.
Dormer cheeks . .	
Chimney and apron flashings . .	
Coverings to cornices.	

Gutters, flats, hips, and ridges.—Not less than 6 lbs.

Sheet Lead.—Sheet lead may be either "milled" or "cast," and is described by its weight in lbs. per square foot, and may be obtained of any weight in multiples of 1 lb. from 3 lbs. upwards. Standard sheets are 7 ft. wide and from 30 ft. to 40 ft. long; different widths up to 9 ft. may be obtained at a slightly increased cost; also any substance either in the form of sheets or plates. The usual stock weights are as follows:—

Milled Lead.

In sheets 30 ft. to 40 ft. long, 7 ft. wide.

3 lbs. per sq. ft. =	1/20″.	Nearest B.W.G.	18.
4 ,, ,,	1/15″.	,, ,,	16.
5 ,, ,,	1/12″.	,, ,,	14.
6 ,, ,,	1/10″.	,, ,,	12.
7 ,, ,,	1/9″.	,, ,,	11.
8 ,, ,,	1/8″.	,, ,,	11.

The thickness of sheet lead in inches may be calculated by multiplying its weight in lbs. per square foot by ·017.

Cast Lead.—Cast lead is sometimes used for external plumbing, especially upon renovations to medieval buildings and where it is desired to re-use the lead; in such cases a casting bench is usually fitted up on the spot. Briefly, the process consists of carefully spreading a bed of prepared sand over the bottom of the casting bench (a wooden bench with rails along the sides and a tipping pan at top) to a thickness of about 1½ in., this is then slightly solidified and trowelled to a smooth surface, the lead being poured thereon from the tipping pan at the head of the bench, the thickness being regulated by a strike—a kind of straightedge—being drawn over whilst the lead is in a fluid condition; the bottom edge of the sheet is immediately cut off to prevent fracture during contraction. Cast lead, owing to the natural positions of its molecules, is less liable to fracture by atmospheric changes than milled lead, in which the molecules are compressed during the process of "rolling." Generally speaking, milled lead is capable of rather greater manipulation in the hands of a skilful plumber. The condition of lead work on many medieval buildings furnishes examples of the permanency of this metal either as a roof covering or for rain-water heads and spouting, &c.

Lead Rain-Water Heads and Spoutings.—Cast lead was at one period largely employed for rain-water heads and spouting; cast iron has of recent years been substituted to a large extent. There is no comparison between the life of the two metals, and the rusting and breaking of cast-iron heads and spouting has been the cause of damage and disfigurement to many buildings, and it is worthy of note that many architects are again adopting lead, which adapts itself to more artistic development. When lead is used for rain-water heads and spouting, care should be taken to insure the fixings being strongly attached to the body of the lead, good length ears or tacks being imperative and the holes strengthened by increased thickness of material and placed close to the head or spouting. For fixing to walls stout lead-headed or copper nails should be used. Seams of lead heads and spouting may be "wiped," soldered with the aid of soldering irons, or they may be joined by "burning."

Lead-Burning.—Lead-burning or autogenous soldering is the absolute fusion of the pieces of lead one with the other, no flux or solder being used. The pieces are first butted together, or they may be lapped over each other and the edges cleaned to remove any oxide; an intense flame is then brought to play on the seam until fusion occurs, any reduction in the thickness of the metal being made good by fusing a stick of lead at the same time. Lead-burning is almost exclusively used for joining lead in chemical works and laboratories where acids would attack lead solders—alloys of lead and tin; it is also largely employed for building up rain-water heads and spouting, and for ornamental lead-work. A special apparatus is required, which may either take the form of a generator in which zinc is immersed in dilute sulphuric acid, the hydrogen gas evolved being mixed with atmospheric air under a slight pressure prior to issuing from the burner; or compressed oxygen in steel cylinders may be used, coal gas being mixed with the same before reaching the burner; this method has the advantage of being ready for immediate use. Where a town's supply is not available, coal gas may be had in steel cylinders.

Soakers.—For rendering watertight the junction of walls, dormers, &c., with roofs, several methods are employed, the best arrangement being "soakers"; the seare pieces of sheet metal, preferably lead or copper, bent at right angles and placed between the slates or tiles to turn up against the wall, &c., as the work proceeds. The required length of soakers for either slates or tiles may be calculated by adding the total length of the slate or tile to the lap and dividing by 2, any additional length required for nailing or other fixing to

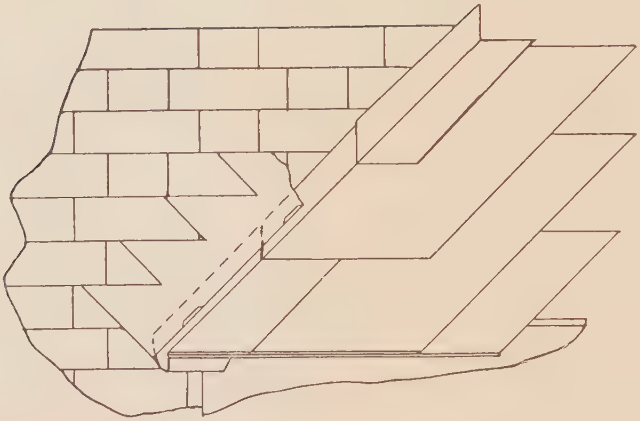


Fig. 18.—Soakers and Step Flashing.

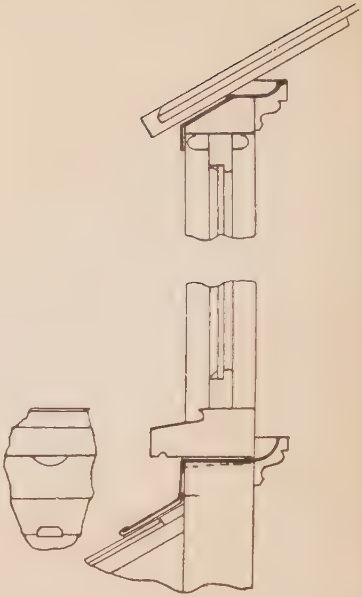


Fig. 21.
Flashings and Condensation Gutters to Roof Lights.

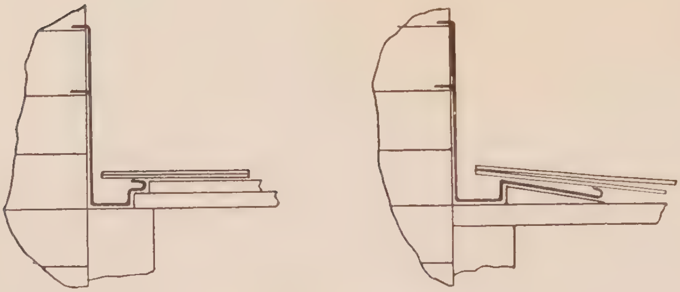

Figs. 19 and 20.—Secret Gutters.


Fig. 23.—Double Welt.

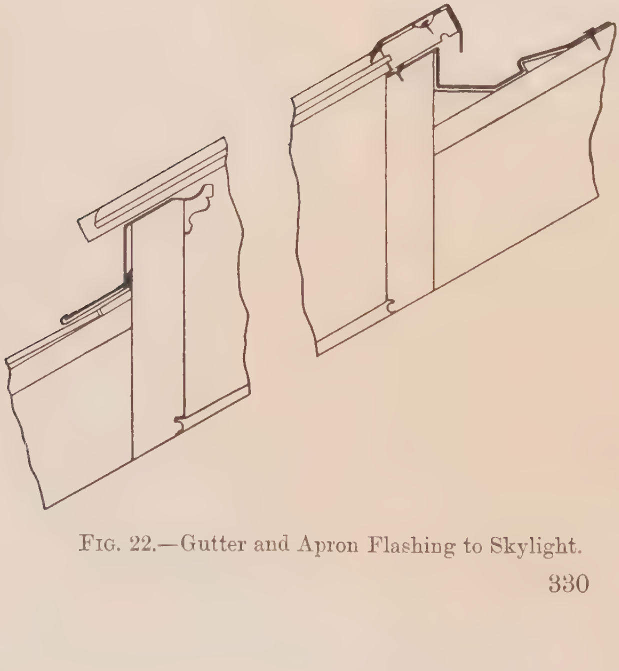


Fig. 22.—Gutter and Apron Flashing to Skylight.

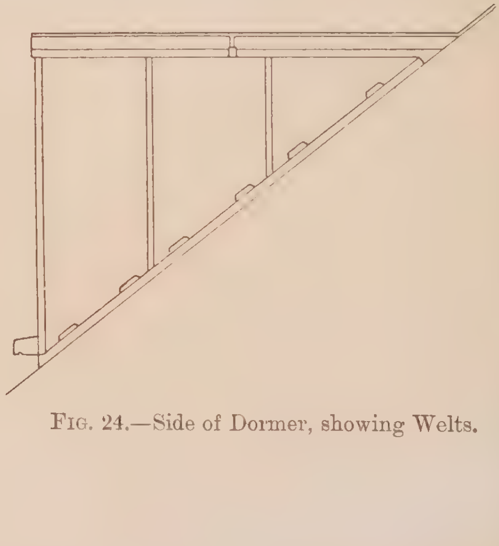


Fig. 24.—Side of Dormer, showing Welts.

be afterwards added; thus a 20-in. slate with a 3-in. lap requires a soaker $11\frac{1}{2}$ in. long, plus, say, 1 in. for nailing. Soakers should turn against the wall to a height of 3 in. and lay under the slates not less than 4 in., preferably half the width of the slates or tiles. It is not necessary to use lead soakers of a heavier substance than 4 lbs. lead, owing to tilting of the slates. Copper may be used of a thinner substance than lead, say 26 B.W.G., which makes an excellent soaker.

Step Flashing.—The upstand of soakers should be covered with a hanging or cover flashing. When soakers are fixed against brickwork the flashing should be stepped into the joints of the same. It is not necessary to employ apron flashing with soakers.

Hip and Valley Soakers.—For mitred hips soakers should be used to prevent leakage at the mitre. The length may be determined as before, the shape being found by bending a piece of lead over the hip and cutting the top and bottom parallel with the horizontal edges of the slating, the sides being cut parallel to the sides of the slates or tiles. Valley soakers are employed in connection with mitred valleys and are of a similar shape to hip-soakers, the length, &c., being determined in the same manner.

Secret Gutters.—Secret gutters are frequently substituted for soakers, and are constructed by forming a channel at the roof junction and lining the same with lead. The principal point in favour of secret gutters is that practically the whole of the leadwork and pointing may be completed before the tiling or slating is commenced; for this reason they are frequently fixed to dormers, chimneys, &c. An objection to secret gutters is that stoppage and subsequent overflowing may be caused by pieces of mortar, slate, leaves, &c., finding their way into the gutter. The width of the gutter should be about 3 in., and from 1 in. to 2 in. deep. When secret gutters are fixed against walls the upstand should be deep enough to stand up 6 in. above the finished surface of the roof and be stepped into the joints of the wall.

Roof Lights.—Roof lights, especially when exposed to driving rains, frequently leak at the sill, owing to the apron flashing being improperly fixed; such apron flashings should always be fixed before the sill is placed in position, the best method being to lay the lead on the curb and afterwards turn the same up on the inside of the sill. Should a condensation gutter be required, the lead may be left of sufficient width for the purpose, grooves being cut in the curb at intervals and the lead dressed into the same to form channels for the escape of condensation; an alternative arrangement is to turn the apron up on the front of the curb and provide a separate piece to lay on the curb and form the condensation gutter. Skylights are frequently found to leak by water passing over the back of the curb; for this reason the curb of skylights should stand vertical and not at right angles with the pitch of roofs.

Dormers.—As in the case of roof lights, the apron flashing should be fixed before the sill and be finished as explained therein. When lead is used for the cheeks of dormers, care should be taken that it is well supported by turning over the top, and that the pieces are not of excessive size. Instead of using large pieces and fixing the same with "soldered dots," it is far better to use narrow strips of lead about 15 in. to 18 in. wide, joining them by vertical welts in which copper tacks—previously screwed to the woodwork—are folded. Such an arrangement avoids the use of dots, and gives greater freedom. The lead to the tops of dormers should turn down over the sides and front, and preferably slope towards the back. The best method of fixing the turned-down edges of the lead is by means of "under tacks" or "welt tacks"; copper nailing should on no account be resorted to.

Gutters and Flats.—It is important that the woodwork, drips, and falls be properly arranged in order to insure a sound and lasting roof or gutter. As previously remarked, the lengths of the pieces of lead should if possible approximate to 7 ft. or under. In placing the rolls for lead flats regard should

FIG. 24A.
Dripping Edge to Top of Dormer.

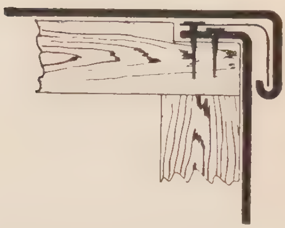


FIG. 25A.
Dripping Edge to Top of Dormer.

FIG. 25.—Nail Welt.

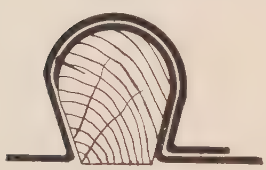


FIG. 26.—Roll to Lead Flat.

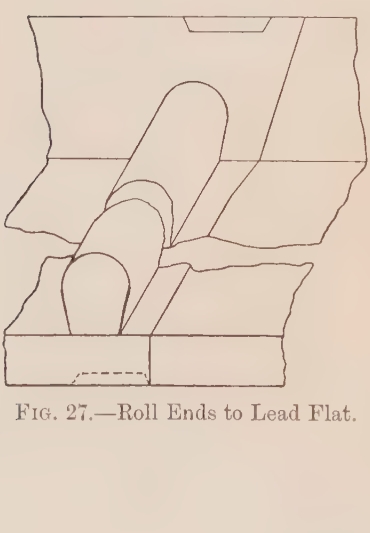


FIG. 27.—Roll Ends to Lead Flat.

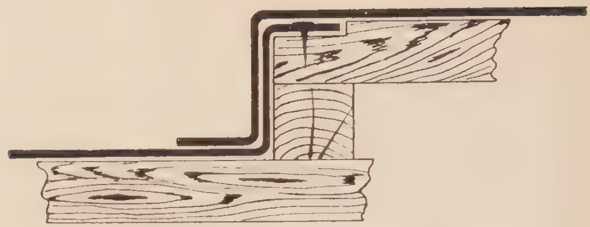


FIG. 28.—Section of Drip to Lead Gutter.

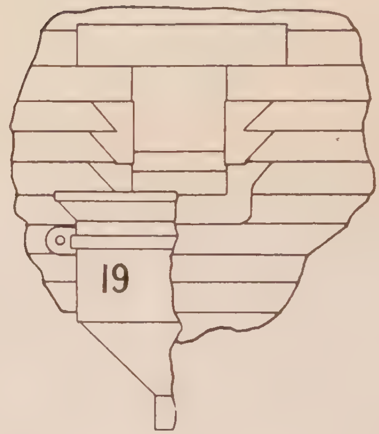


FIG. 29.—" Shute " Discharge over R. W. Head.

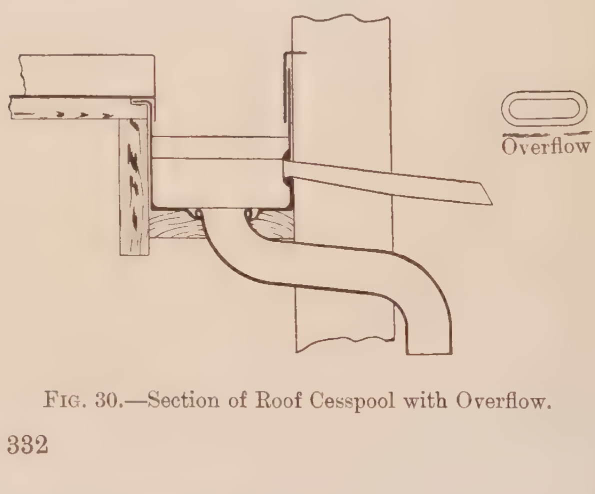


FIG. 30.—Section of Roof Cesspool with Overflow.

be had to the width of the sheets of lead to be used or waste may occur; the width of the bays should be arranged to enable a sheet of lead to be cut down the centre; with a standard (7 ft.) sheet this would be 3 ft. 6 in. and the distance between the rolls should be 2 ft. 8 in.,

Fig. 31.—"Bird's Mouth" Outlet to Cesspool.

allowing 3 in. for "undercloak" and 7 in. for "overcloak."

Roof, Cesspools, and Shoots.—Where possible, the best arrangement for discharging the water from lead-lined gutters is to allow the gutter to pass through the wall and discharge over a hopper head, forming a "shoot." Where the foregoing is undesirable, cesspools

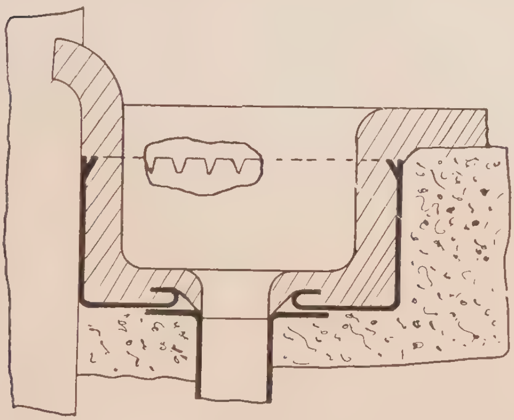


Fig. 32.—Lead Cesspool to Asphalt Flat.

may be used; the outlet pipe should be wiped in, and an overflow—also wiped in—provided; care should be taken to keep the overflow below the drips discharging into the cesspool. Lead cesspools are frequently provided to asphalt flats and gutters; by their use a sound connection may be made between the outlet pipe and asphalt.

Covering Stone Cornices.—Stone cornices, especially when of large dimensions, are frequently covered with lead. To allow of movement where the cornices weather outwards it is best to turn the lead up on the face of the wall, and not bed the same as the erection of the wall proceeds. The pieces of

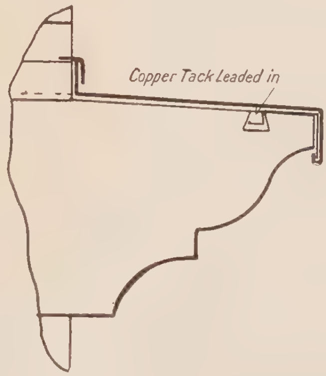


Fig. 33.

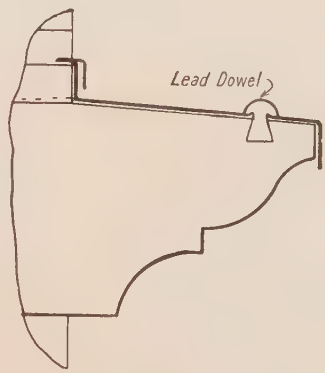


Fig. 34.
Lead Coverings to Stone Cornices.

lead may be joined by welts, raised or sunk. Where cornices weather inwards, a channel or gutter is formed into which the lead is dressed; if the cornice will permit of shallow drips being formed it is preferable, as it permits the lead to be used in smaller pieces than when drips are not possible. To prevent the lead being blown up soldered dots are sometimes used; these, however, hold the lead too rigid,

resulting in a fracture around the edges of the dots; a much better method is to form lead dots similar in appearance to rivets, or to run in lead "under tacks" and turn the lead under the same as in securing the edges of lead on dormer tops. W. F.

Plumbism.—Another name for "lead-poisoning" (*see article* "WATER SUPPLY," action of water upon lead).

Polarite (*see* "INTERNATIONAL PROCESS OF SEWAGE PURIFICATION") is the commercial name for magnetic spongy carbon which is obtained from a certain kind of iron found in parts of South Wales. This material has been tested by Sir H. Roscoe, F.R.S., who has stated that the "porous nature of the oxide, its complete insolubility, and its freedom from rusting, constitute its claim to be considered a valuable filtering material."

Population, Estimation Of.—In Great Britain and Ireland a census enumeration of the population is undertaken every ten years, and it is therefore only once every ten years that we have the exact numbers and ages of those living in any community. During inter-censal periods the population has to be estimated, and there are several ways of effecting this. One simple method of obtaining a close approximate estimation involves an enumeration of the number of inhabited houses in the district (a figure obtained from the rate books), and allotment to each such house of the average number of inhabitants found to be occupying a house at the last census. The average number of persons per inhabited house may vary from 4·5 to 9 according to the size of the house and the social class of the occupants; according to the census of 1901 it was 5·19 in England and Wales. In addition to the number thus calculated one individual should be allowed for each empty house, in order to account for caretakers and their families. Another means of estimating the population is by the birth-rate, where this remains fairly constant for a series of years; under the latter circumstance and when applied to large populations the computation is found generally to closely approximate to the truth. By this method the population is represented by the number of registered births in the year multiplied by a thousand and then divided by the mean birth-rate for the previous ten years. The practical drawback to this method is that the population of the current year cannot be estimated, inasmuch as the data for the calculation are not available except in respect of a past year. On the whole the method used by the Registrar-General is the most satisfactory and serviceable. It involves the use of logarithms and is carried out as follows:—from the logarithm of the population according to the last census is deducted the logarithm of the population from the immediately preceding census. The difference will indicate the logarithm corresponding to ten years' increase in the population. A tenth of this figure will represent the logarithm of one year's increase. Now assuming that it is five years since the last census was taken we shall then have to provide for five years' increase in the population, together with an extra quarter of a year's increase, in order to take into account the fact that the census was taken at the end of the first quarter of the year and the population is always estimated to the middle of the year. The logarithm of one year's increase is therefore multiplied by $5\frac{1}{4}$ and the result represents the logarithm of $5\frac{1}{4}$ years' increase; this, added to the logarithm of the population by the last census, gives us the logarithm of the population five years later, and the number corresponding to this logarithm furnishes the calculated population. This method assumes that the population is increasing or decreasing, since the last census, in the same ratio as between the last two censuses, and it is here that a fallacy may arise: and the estimates of population so obtained often present a considerable departure from the actual truth when fresh census figures become available for comparison.
H. R. K.

Pneumatic Sewage Lifts. (*See* "EJECTORS.")

Precipitating or Settling Tanks.—In any system of sewage treatment the first stage towards purification is the removal of the grosser solids such as rags, fæces, orange peel, sticks, miscellaneous small articles thrown down the drains, and road silt, sand, &c. This is done by means of preliminary screening, followed by precipitation in tanks either with or without the use of chemical precipitants. Such tanks are constructed either upon the "absolute rest" principle (*see* "ABSOLUTE REST PRECIPITATION TANKS") or upon the "continuous flow" method. The latter is the plan most generally adopted, as it economises tank capacity and fall in construction. The sewage should not pass through the tank in less than two hours, and suitable chemicals are requisite for producing the clearest of effluents. For purely domestic sewages such tanks may be provided with a number of submerged cross-walls carrying iron screens, and these, together with scum-plates, remove sufficient of the suspended solids preparatory to the second stage of the purification process without entailing the expense of chemical precipitants. It may be worked either intermittently or continuously, and should be cleaned out once every three days, or at least once a week. If not cleaned frequently the deposited sludge soon ferments, generates gas, and foul matter is carried to the surface of the liquid, which spoils the quality of the effluent. Taking the maximum sewage flow per hour at 8 % of the daily flow, and allowing for a minimum of 2 hours' stay in the tank, the capacity should be 16 % of the total sewage to be dealt with. To meet practical working conditions this volume should be multiplied by 3, which would thus bring the total tank capacity up to say 50 %. This should be divided amongst three or more independent tanks, so that whilst one tank was empty for cleaning, two would be available for the ordinary sewage and fluctuations in storm flow. It will be obvious that the division of the tank room into several small tanks will be more serviceable in practice than the same capacity in larger units. If the tank liquor is to be passed on to filters formed of fine grade material, the period of flow through the tank would require to be increased to 10 or 12 hours. Precipitation tanks are used "in parallel" or "in series." With ordinary sized tanks the minimum rate of flow is obtained by the former method. Where tanks are worked "in series," after a certain percentage of solids has settled out, no great advantage is gained by passing the sewage through another tank at the same rate. For further deposition of solids quiescent settlement is necessary. For various special forms of settling tanks, *see articles on* "DORTMUND SETTLING TANK," "COSHAM PRECIPITATING TANK," "IVE'S TANK," "CANDY SETTLING TANK," and "DUNDRUM SETTLING TANK."

W. H. M.

Precipitation Tanks. (*See* "SEWAGE DISPOSAL.")

Privies.—Frequently made use of for cottage property in country districts in the absence of water-closets or suitable conditions for earth closets. They are of two kinds: privies proper, intended for excrementitious matter only, and privy-middens, provided for the disposal of ashes and general refuse in addition to excreta. In the former the excreta is collected in a pail or other suitable removable receptacle which by the Model By-laws is restricted in capacity to a maximum of 2 cub. ft., so as to insure frequent emptying. The privy apartment should be provided in the open and have no direct communication with the dwelling-house. The floor must be of non-absorbent material and at least 6 in. above the surrounding ground, while that portion under the seat on which the pail rests must not be less than 3 in. above the ground. The apartment should be well lighted and must be ventilated by at least one opening communicating directly

with the open air and placed as near as possible to the roof. The walls of the space enclosed by the seat must be impervious, and the pail should be removable from the outside. Privy-middens are usually provided with a fixed receptacle or non-absorbent pit, which by the Model By-laws is limited to a capacity of 8 cub. ft. to ensure at least weekly removal of its contents. This pit is most conveniently so built that one-half is situated in the privy apartment, while the other half projects outside the building. Over the former the seat is fixed, over the latter half a flap is provided through which ashes and other dry house refuse are thrown in. That this should be regularly mingled with the excreta is important. A coarse sieve may be provided in the opening for the purpose of screening the ashes from the cinders. With the exception of the receptacle, the construction of the privy apartment does not differ from that above described.

Public Health. (*See* "Hygiene and Public Health.")

Pumps and Pumping Machinery.—The principle of the action of the pump, like that of the siphon and other similar hydraulic applications, depends upon the balance of weight between a column of water of a certain height and the atmosphere. The best results are obtained from 10 ft. to 15 ft., and with high speeds the shorter the suction the greater the efficiency.

The different classes of pumps here illustrated are the common suction pump (Fig. 1), the lifting pump (Fig. 2), the single-acting piston pump (Fig. 3), the plunger pump (Fig. 4), the horizontal plunger pump with air vessel (Fig. 5), the double acting piston pump (Fig. 6), and the combined plunger and bucket pump (Fig. 7). In all of them the suction valve must be within the usual limit of height from the surface of the water to be raised, but by a suitable arrangement of valves within the barrel of the pump the water may be lifted to any desired elevation. Thus in Fig. 2 it will be observed that the common suction pump is converted into a "lifting pump" by attaching a rising pipe in the place of the ordinary spout and placing a valve at the

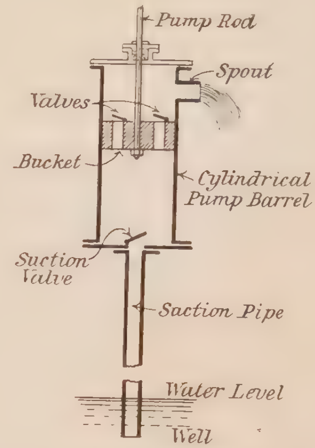


Fig. 1.—Common Suction Pump.

lower end of this pipe to prevent the return of the water. As this modification causes considerable pressure within the pump-barrel, its upper end is securely covered down and the

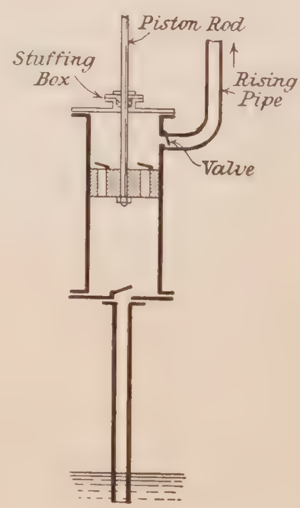


Fig. 2.—Lifting Pump.

piston-rod works through a stuffing-box as shown. It is clear that each rise of the piston forces some portion of the contents of the pump-barrel upwards into the rising-pipe, also

that the power required to work the pump must be sufficient not only to fill the barrel from below but also to lift the column of water in the rising-pipe. The retaining valve at the foot of the rising pipe is not necessary to the action of the pump because, the barrel being full, the suction valve retains the water, but it is employed as an additional check and relieves the valves below it of excessive pressure and prevents leakage.

"Stuffing-Box."—An enlarged sectional view of a "stuffing-box" is given in Fig. 8. It may be described as a device for rendering a joint impervious where there is a hole through which a movable cylindrical rod or plunger, such as the piston rod of a steam engine or

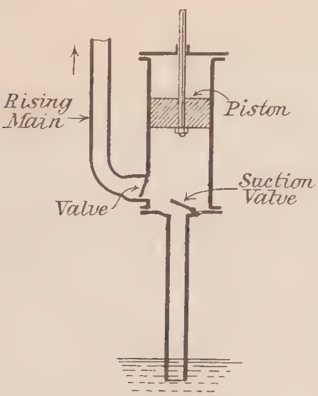


Fig. 3.—Single-Acting Piston Pump.

the plunger or rod of a pump, slides to and fro, and which requires to be kept water or steam-tight under pressure. Generally, it consists of a box or chamber, made by an enlargement of part of the hole, thus forming a space around the piston rod for containing packing which is pressed home and made to tightly fill the space by means of a sleeve, called a "gland," fitting loosely around the rod, and pressed down upon the packing by tightening the bolts shown in the illustration attaching the gland to the box.

The single acting piston pump (Fig. 3) is used to force water up to any required height. It differs from the lifting pump in that the piston contains no valve and the top of the pump barrel need not be covered down. A little water poured in at the top of the barrel makes the piston air-tight. When the piston is raised, the valve at the foot of the rising-pipe closes and the suction valve opens, admitting water from below into the barrel. Upon the return of the piston downwards, the suction valve closes and the retaining valve (at foot of rising-pipe) opens and water is forced up the pipe.

In the plunger pump (Fig. 4), the delivery is on the down stroke as in the case of the pump last described, and the action of the valves is also similar. In this case, however, a solid plunger is substituted for the piston, whereby the expense of turning the cylinder

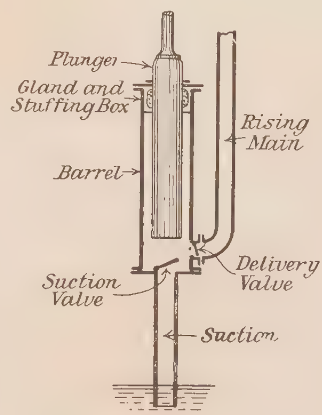


Fig. 4.—Plunger Pump.

true is avoided, and the plunger also better resists the wear from grit, &c., within the pump barrel. The top of the barrel must, however, be tight, and the plunger therefore works through a gland and stuffing-box. At each stroke this pump raises a volume of water equal to that of the plunger.

A plunger pump with air vessel attached is shown in Fig. 5. The object of this is to make the working of the pump smoother and the flow of the water more uniform. The air vessel is attached at the foot of the delivery pipe, and, during the inward stroke of the plunger, part of the water leaving the pump-barrel passes into the delivery pipe and a

portion into the air vessel and compresses the air contained in its upper end. On the outward stroke the air thus imprisoned and compressed exerts a force upon the water and forces it out into the delivery pipe, thus maintaining a more uniform flow, and acting as a sort of cushion to absorb the otherwise marked effect of each stroke of the plunger. An air vessel also economises the power employed to work the pump as it imparts to the water a constant forward motion.

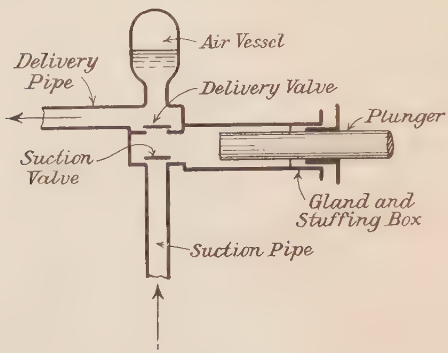


FIG. 5.—Plunger Pump with Air Vessel.

In the double-acting piston pump (Fig. 6) there are two suction valves and two delivery valves placed as shown in the figure, all opening to the left. Water is delivered upon both the up and down strokes. On the up stroke, water enters the pump barrel through the suction valve D, and passes into the rising-pipe through valve A. On the down stroke, water is forced through valve C, and enters above the piston at valve B, thus maintaining a constant discharge.

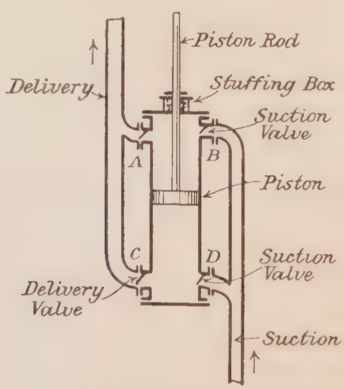


FIG. 6.—Double-Acting Piston Pump.

The double-acting pump shown in Fig. 7 is a combination of a plunger pump discharging water on the inward stroke and a bucket pump discharging on the outward stroke, thus giving a continuous flow. The area of the cross-section of the plunger is made half that of the pump barrel, so that on the up stroke half the water raised by the bucket goes to fill the space left by the plunger and the other half is passed up the rising-pipe. On the down stroke the plunger displaces half of the water raised by the bucket and forces it into the delivery pipe. This form of pump was invented by Perkins, introduced at the Lambeth Waterworks in 1848, and is extensively used in most of the large waterworks.

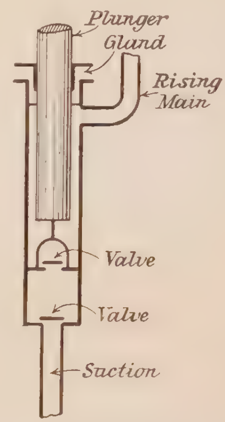


FIG. 7.—Combined Plunger and Bucket Pump.

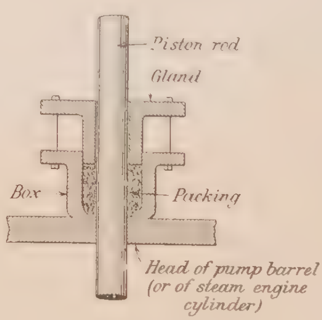


FIG. 8.—" Stuffing-Box."

The working barrels, buckets, and valves of pumps should be made of brass, gunmetal, or phosphor-bronze, as, though initially costly, these metals will be found to be more durable and give greater satisfaction in working. They are not liable to corrosion by the action of the water, will be found more accurate in their operation than iron, and are less liable to injure the leather attached to the bucket and valve, which are parts frequently requiring attention and repair. In force pumps the

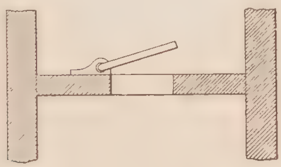


FIG. 9.—Clack Valve.

packing of the piston or box is an important matter, and is usually made of waste tow soaked in tallow and rammed tight, or, where there is great pressure, cup leather packings are employed. In the close-topped pumps working through a stuffing-box the rising-pipe and suction are frequently made about two-thirds the area of the working barrel. In the case of quick-running pumps the diameter of the suction should not be less than that of the working barrel, and every means should

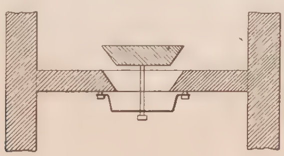


FIG. 10.—Conical Valve.

be adopted to enable the water to reach the pump very readily.

The force required to work a pump, or the pull on the pump rod, is equal to the weight of a column of water having a base equal in area to that of the bucket or plunger, and a height equal to the height to which the water is being raised.

For hand pumping from ordinary wells under 30 ft. in depth, a convenient size of pump for one man to work is a 4 in. working barrel with a 9-in. or 10-in. stroke. This pump will throw 24 gallons per minute from a 20-ft. well. Between the depths of 30 ft. and 70 ft. a $3\frac{1}{2}$ in. diameter working barrel with a 9-in. or 10-in. stroke may be employed, but for wells over 70 ft. a strong three-throw pump consisting of three working barrels standing side by side upon a horizontal valve-box common to the three barrels, and worked from the top by means of pump-rods actuated

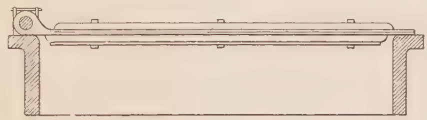


FIG. 11.—Flap or Hinged Valve.

by a three-throw crank, wheel and pinion, driven by either horse-gearing or steam oil or gas power, will be found the most suitable type.

PUMP VALVES.—Pumps are placed between the water to be raised and the point of delivery, and have, therefore, to perform two distinct operations, viz., to suck or draw the water into the pumps, and then to force it to the required elevation. Valves are therefore a necessity for the control of the water so raised, their function being to open freely to the forward

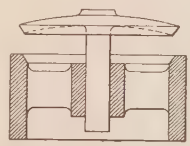


FIG. 12.—Conical Disc Valve.

motion of the water and to close against its return, and so prevent loss of the work done by the pump, piston, or plunger in giving the water its forward motion. The valves of every pump thus form a most important part of the apparatus and require careful attention in their design and maintenance, otherwise a large proportion of the power expended in pumping will be lost through excessive friction or "slip," and the cost of pumping per 1,000

gallons raised will become excessive. To prevent slip the valves should offer little resistance to the passage of the water in one direction and close quickly and tightly in the opposite direction, but without shock. The construction of the valves of a pump largely determines the speed at which it may be worked. For fast working low lifts are necessary. The weight of a valve should be sufficient to close without knocking, and should at the same

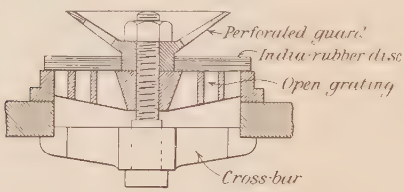


FIG. 13.—India-rubber Disc Valve.

time be light enough to be lifted without great resistance to the water. In the case of high lifts the weight of the valve is very generally estimated at 1 lb. per square inch of area, equal to a head of about $2\frac{1}{3}$ ft. of water, whilst for low lifts it may be from $\frac{1}{4}$ lb. to $\frac{1}{2}$ lb. per square inch of area. A small lift in a valve is desirable, as it enables the valve to close quickly, thus reducing shock as well as slip. The velocity of the water through a

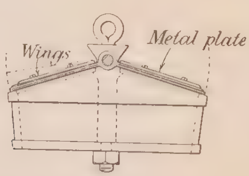


FIG. 14.—Butterfly Valve.

valve should not exceed about 5 ft. per second, and in a well-made pump the slip should not exceed from 5 to 7 %. Valves of the "butterfly" type allow more slip than "double-beat" valves.

Various classes of valves are shown in Figs. 9 to 16; generally speaking, they may be divided into two classes, viz., hinged or door valves, and spindle valves. The ordinary "clack" valve and "conical" valve as used in the common suction pump are shown in Figs. 9 and 10. The flap or hinged valve consists of a flap of stout leather stiffened with metal plates and working on a hinge. Fig. 12 shows a conical metal disc valve working on a central spindle. The conical edge

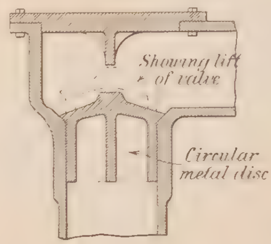


FIG. 15.—Mitre Valve.

fits accurately upon a corresponding seating sloped at an angle of 45° with the valve axis. The lift of the valve is limited by a stop placed above it, and the amount of the rise should not exceed one-fourth of the diameter of the valve. An india-rubber disc valve is given in Fig. 13; it consists of an open

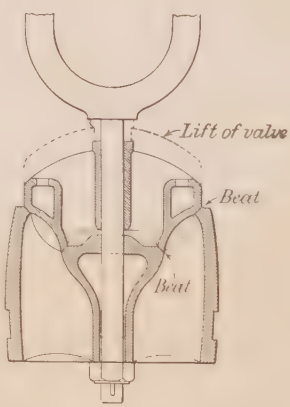


FIG. 16.—Double-Beat Valve.

grating covered with a disc of india-rubber surmounted by a perforated guard, against which the force of the passing water raises the india-rubber. On the return of the water pressure downwards the india-rubber is forced back tightly upon its seating. The apertures in the grating are made at an angle, thus producing a circular motion in the valve as

the water passes through, which prevents the valve falling in the same position and cutting the rubber. Strong dark-blue rubber is used for heavy work. The "*butterfly*" valve (Fig. 14) is formed of semi-circular discs hinged at the centre as shown, and is made of leather and metal plates similar to the hinged valve. The mitre valve (Fig. 15) consists of a circular metallic disc with conical face. The short stop above the valve limits its lift, and feathers below guide the valve on to its seat. The "double-beat" valve (Fig. 16) is an extensively used form of valve, and was designed to overcome the great wear and tear of the flap valves. It consists of two circular rings on which the upper and lower parts of the valve respectively beat, thus forming the "double beat," as illustrated. The beats are of lignum-vitæ, leather, or white metal, and are fixed to the valve and beat on a gun-metal seat. Owing to the two openings for discharge, this valve has the advantage of a small lift, and the shock caused by closing is thus reduced in consequence. The webs connecting the parts together, being made at a slight angle, cause the valve to rotate during the passage of water, which tends to keep the beats perfect and to prevent grooving. In the double-beat valve adapted for heavy lifts the bottom beats are usually of gun-metal and the upper ones may be of hippopotamus hide or similar leather.

More complicated valves than the foregoing are also used, such as three- and four-beat valves, made on the same principle as those referred to above, and taking their names according to the number of the beats.

The Riedler valve has been largely used on the Continent with much satisfaction, and has also been employed in four compound pumping engines supplied to the Grand Junction Water Co.'s works at Hampton. In ordinary pumping engines of this class it is difficult to run fast owing to the concussion and vibration occasioned by the sudden closing of the pump valves at the end of each stroke. In the Riedler engines the pump valves are mechanically closed much in the same way as the valves of a steam-engine, and by these means the difficulty of fast running is overcome.

In the design of pump valves it should be borne in mind that all types break up and impede the advancing water column to some extent in passing through the pumps, and that in this way friction is caused and a certain proportion of power of the engines is consumed. The object to be aimed at, therefore, is to reduce these losses to a minimum by avoiding unnecessary division or deflection of the water by the valves and short bends or contractions in the water passages. Formerly, the increase of the sizes of valves in the building of large pumping engines gave rise to considerable shock and vibration upon the valves coming upon their seatings, the impact of which often made the whole machinery and buildings shake. This difficulty led to the practice of dividing the valves into nests of the double-beat form, and in many large works the valves are of the four-beat class, or Husband's model. The valves of some pumps are also divided into nests of a dozen or more of the rubber-disc type as above described, and by this means the shock of the water-hammer produced when the valve falls on its seat is reduced, but each sub-division increases the frictional resistance to the flow. Pumps of the "Worthington" type and many modern steam fire-engines are fitted with nests of rubber-disc valves, this class being largely used where the motion is rapid and the pressure great.

For general waterworks use valves of the "Cornish" class are in great favour, but the more complicated modifications of this type sometimes give trouble from noise, vibration, sticking, and undue friction. For metal valves flat faces are as a rule better than conical faces, especially if the water is gritty. Sharp angles or bends should be avoided and all connections made with easy curves. Where bends are unavoidable air cocks should be provided for the escape of the air and to insure good circulation of the water. Clack valves are sometimes used for low lifts on small pumps where the water contains much

sand, and when this class of valve is used for larger pumps a small valve is provided on the top of the large one to reduce the shock, as the small valve, on account of its smaller area, closes and opens first, and so relieves the impact of the water.

Miscellaneous Types of Pumps.—In addition to the classes of pumps already referred to, there are several kinds largely employed for various purposes, *e.g.*, the centrifugal, the pulsometer, borehole pumps, the semi-rotary, and the high lift turbine pump.

Centrifugal Pumps are much used where large quantities of water have to be raised through low lifts, such as for the drainage of low-lying land, as in the fen districts, emptying docks and reservoirs, raising large quantities of storm-water, pumping on to filter beds, and other like purposes. Centrifugal pumps are driven at a rapid speed by means of good wide belts from shafting, or by a steam-engine combined direct with the pump. Having no valves, the centrifugal pump lends itself well for the pumping of sewage or other liquids carrying a large proportion of solid matter in suspension, but it is desirable to exclude such matters as pieces of yarn, rope, cloth, &c., by means of a coarse screen or grid on the suction. The duty of the centrifugal pump below 20 ft. lift compares favourably with any other class of pump, but above that height the efficiency falls off. A maximum efficiency of about 70 % is reached at from 15 ft. to 20 ft. lift. The speed of the water should not exceed about 8 ft. per second, and sudden changes in its path through the pump should be avoided as far as possible.

The Pulsometer Pump is an indispensable appliance for contractors' use upon engineering works where large quantities of dirty water may have to be removed. It is easily and quickly suspended in almost any position, and is operated by the admission of steam from the top past the steam ball valve. This presses upon the surface of the water contained in the body of the pump, thus depressing it and driving it through the discharge outlet into the rising main. The steam pressure at the pump should not be less than from 20 lbs. to 30 lbs. per square inch for lifts from 20 ft. to 40 ft., and from 30 lbs. to 50 lbs. for lifts between 40 ft. and 80 ft.

Borehole Pumps are fitted in a working barrel inside the steel lining of the well and placed at a sufficient depth to insure a good draught of water. The pumps are commonly worked from a bell-crank in the engine-room by means of iron guides steadied by guides working against the lining of the well. Such pumps should be drawn for inspection and overhauling at periodic intervals, as the wear and tear is often considerable.

The Semi-Rotary Wing Pumps of the "Willcox" type are very useful for temporary purposes, and have a high capacity compared with the small power required. The pumps suck vertically a height of 25 ft. with the use of a suction or foot valve, and will deliver to a vertical height of about 110 ft.

Piston or Plunger Speed of Pumps.—The possible speed of the plunger depends upon the proper filling of the pump during each single stroke. The readiness with which such filling takes place depends greatly upon the size and design of the suction valves, and upon the length of the stroke.

The length of suction, suitable plunger speed and length of stroke, and the good design of the pump valves, are first essentials to the smooth and satisfactory working of pumps, freedom from "knocking," and other troubles.

It is impossible to lay down any fixed rule as to the plunger speed of a pump, since this will vary with the different conditions to be met.

Usually the longer the stroke, and the greater the ease with which the water reaches the pump, the greater the piston speed permissible. A high piston speed in an engine tends to economical working, as the cylinders, having less time during which to become cooled between the successive admissions of fresh steam, give less loss from initial condensation. In order to secure the advantage of a high steam-piston speed with a low

pump-plunger speed; gearing is frequently resorted to, but usually with some unavoidable sacrifice of mechanical efficiency. The mean piston speed of an engine is ascertained by multiplying twice the stroke in feet by the number of revolutions per minute. Thus, an engine having a 40-in. stroke and making 23 double-strokes per minute, has a piston speed of 153·4 ft. per minute. Vertical direct-acting pumping engines usually run at from 20 to 25 revolutions per minute.

Pounding in pumps is a common trouble and may arise from too sudden closing of the valves, through the valves having too great a lift, or from other defects in the water cylinder. Want of lead in the steam valve, insufficient clearance, defective piston rings, and worn bearings may also produce the pounding effect. Too heavy a duty for the pumps is another cause.

Packings to piston rods of steam cylinder and to pump pistons is a practical detail of much importance. Neglect on this point may lead to serious scoring or grooving of the piston rod, to undue friction on the rod causing waste of power, to leakage of steam, and other defects. Some of the materials which have been used for steam cylinders are asbestos, spun yarn, hemp, French chalk, metallic packing, and ordinary cotton rope with a French chalk core. With all packings the stuffing-box should not be over-filled, and the gland should be screwed up evenly all round.

For the packing of pump pistons leather of the best quality, layers of cotton and rubber, and metallic rings of cast iron, steel, and gun-metal are used. Springs are employed to expand some of the metallic packings, but these require careful adjustment or an uneven and unnecessary frictional loss may be caused. For large pumps plaited hemp makes a good packing, and for small pumps ordinary gasket is used when well greased with tallow.

Selection of Pumping Machinery.—In the great majority of waterworks the provision of the most suitable and efficient class of pumping machinery forms a leading factor in their proper equipment and design.

Great variety exists in the class and arrangement of machinery which may be employed, and in practice each case will require to be separately considered in the light of the special circumstances to be met. The engineer must take into account the question of the most suitable type of machinery for the case in point, the capital cost of the engine, pumps, boilers, buildings, foundations, and other accessory works; and also the probable annual working expenses which will be incurred in wages, fuel, repairs, and other charges. The class of motive power to be adopted and the convenience for the delivery of fuel to the site should also largely influence the decision.

It is usually advisable to carefully compare the cost of alternative proposals, and for this purpose the various items of yearly expenditure should be capitalised and added to the initial cost of the buildings and plant involved by each alternative proposal, so that a comparison upon an equal basis may be made.

In motive power the various alternatives lie mainly between steam, gas, oil, and electricity—the final choice depending largely upon the size of the water undertaking, the relative prices of coal, gas, or oil delivered to the site, and other special facilities which may operate in favour of any one of these agents named in preference to others.

Where there is a large amount of pumping to be done, high pressure steam used expansively will usually be found to be by far the most economical and reliable motive power; but in the case of small rural works, or at small isolated stations of larger undertakings, gas and oil engines will frequently be found the most serviceable and convenient agents to employ. The latter will also be found advantageous in cases where the pumping is intermittent and continued for short periods only according to requirements.

In every pumping works it is necessary to have a certain proportion of "stand-by" plant in order that the regular supply to the town may not be interrupted in the event of a temporary break-down of an engine or any

part of the machinery. In small works it is customary to have the pumping plant in duplicate, but in large stations this is not necessary as here the pumping power is usually made up of a number of pumping units, the break-down of any one of which will, as a rule, not seriously incommode the supply. In such a works the stand-by plant need not be more than one-third, one-fourth, or even one-fifth of the whole, according to the size of the works, the power of the pumping units employed, and the amount of high level storage between the pumps and the water consumer.

Another important question affecting the amount and arrangement of pumping power and the quantity of stand-by plant required is the system upon which the supply is delivered into the town. Where the water is pumped direct into the mains, the pumps must be fully equal to the maximum rate of supply and must closely follow the fluctuations of demand during the different periods of the 24 hours. There must be ample stand-by plant, and the whole pumping arrangements and staff must be ready to meet any emergency promptly, whether it be from break-downs, excessive consumption through drought, leakage, fire, or other causes. A more satisfactory mode of supply, and one entailing less anxiety at the pumping station, is that in which the engines deliver into a high-level storage reservoir containing a day or two's consumption, or oftentimes much less, upon which the town may draw during a temporary cessation of pumping. Again, where there is no such reservoir, the fluctuations of consumption are balanced for brief periods in some cases by the use of stand-pipes and water-towers. W. H. M.

Purification of Water. (*See* "FILTRATION.")

Rain-water Cistern, Venetian.—Rain-water reservoirs are the chief sources of water supply along extensive tracts of the Italian coast. In most parts of the country the reservoirs, like those of the East, are entirely or partly sunk in the ground and covered over, the rain from roofs passing through strainers before entering the cistern. The Venetian type is an improvement on the above. The cistern is divided into two equal sections by means of a partition descending from the domed or flat roof to within a few inches of the bottom. Both sections are half filled with filtering materials, generally consisting of three layers of equal thickness—sand being at the base, protected by a layer of fine gravel, with coarse gravel on the top. Rain passing through strainers enters one section of the cistern, and passing downwards through the filtering material makes its way through the slit at the base of the partition into the second division rising through the filtering materials. The water is raised from this section either by means of buckets, an opening in the roof, generally arched over to afford protection, being provided; or, better still, by means of a pump. A sealed manhole should be placed in the roof of each section. In this country, where the air is apt to be contaminated with dust and soot, it is advisable to use a "rainwater separator" (*q. v.*) in place of an ordinary strainer. Rainwater from a cistern built on the above principle by Dr. Poore at Andover was analysed chemically and bacterioscopically by the Royal Commission on Sewage Disposal in 1901, with the following result:—

PARTS PER 100,000 BY WEIGHT.

Ammoniacal nitrogen		0·064
Albuminoid ,,		0·020
Nitrite		0·033
Nitrate		0·086
Oxygen absorbed from permanganate at 80° F.	at once	0·23
	after 4 hours	0·48
After incubation at 80° F. for 6 days	at once	0·23
	after 4 hours	0·79
Combined chlorine		0·16
Dissolved oxygen (parts per 1,000 by volume)		2·8

25 bacteria per c.c. were found on gelatine at 20° C., and 7 per c.c. on agar-agar at 37° C. Tests for *bacillus coli* and *b. enteriditis sporogenes* gave negative results.

Rain-Gauge.—This is an instrument for measuring the rainfall. It is best made of copper, and should have a circular funnel of 5 or 8 in. diameter. It should be of the Snowdon pattern—that is, have a deep rim to retain snow—and should be placed with its rim 1 ft. above the ground, in an open and well-exposed situation. The measurement of the rain is affected by pouring out the contents of the can or bottle into the glass measure, and reading off to hundredths of an inch. The gauge should be examined daily at 9 A.M., and the rainfall, if any, entered to the previous day. When snow falls, that which is collected in the funnel should be melted and measured as rain. By an inch of rain is meant the height to which the water would stand on the level, provided it did not run off, or soak into the ground, or evaporate. An inch of rain over an acre of surface is equal to 101 tons of water. In mountain districts where the rain-gauge can only be visited once a month, the inside can should be large enough to hold 20 or 30 in. Self-recording rain-gauges such as those by Halliwell, Negretti and Zambra, Beckley, Richard, &c., yield most valuable data on the rate of fall, the intensity, and the duration of rain. To the engineer and surveyor information on rainfall is most important. Where sewage has to be pumped it is necessary to know what has to be provided for as an average, and what as a maximum, so that the engineer may know when he will have to give up pumping and have resort to storm overflows. The matter of water supply is, to a great degree, a question of the quantity of rain that can be depended on. W. M.

Rams, Hydraulic. (*See* "HYDRAULIC RAMS.")

Reeve's System of Sewage Treatment.—In this system a chemical precipitant and deodorant called "thamisin" is used in both the sewage and the sludge treatment. The sewage is then settled in tanks, the top water drawn off and treated on land or filters, and the sludge disposed of on land as a fertilizer. The process is in use at Staines and Henley.

Refuse Collection. — The powers and obligations of local authorities in the matter of refuse removal are dealt with in sections 42 and 43 of the Public Health Act, 1875, to which reference should be made. Any person who obstructs the local authority in carrying out their duty under these sections is liable to a penalty for each offence of £5, whilst, on the other hand, if the authority have themselves undertaken or contracted for the removal of house refuse from premises, and, after written notice from the occupier, fail, within seven days, to remove such refuse, they are liable to pay to the occupier of such house a penalty not exceeding 5*s*. for every day of default.

When organising a system of refuse collection it is important, at the outset, to know exactly what classes of material are to be removed. These generally include domestic house refuse, trade and shop refuse, garden refuse, and street refuse. These terms are not defined by the Public Health Act, 1875, and are somewhat indefinite in their use and application, and differences occasionally arise with householders as to what classes of material are to be removed. It is important, therefore, the matter should be made as clear as possible to all concerned to avoid misunderstandings. Some help is afforded by the Public Health (London) Act, 1891, which contains the following definitions:—

"House refuse" means ashes, cinders, breeze, rubbish, night-soil and filth, but does not include trade refuse.

"Trade refuse" means the refuse of any trade, manufacture, or business, or of any building materials.

"Street refuse" means dust, dirt, rubbish, mud, road scrapings, ice, snow, and filth.

"Ash-pit" means any ash-pit, dust-bin, ash-tub, or other receptacle for the deposit of ashes or refuse matter.

The material to be collected usually consists in varying proportions according to the locality and habits of the people, principally of cinder

and ashes, coal and coke, fine dust, straw, rags, waste paper, bones, vegetable and animal refuse, bottles, glass, crockery, old iron and tins, hardware, &c. Of this material London is said to produce about $1\frac{1}{4}$ million tons per annum or about 4 to 5 cwt. per head per annum. In the North of England an average of about 8 cwt. per head per annum is collected. The actual amount in any given case will, however, vary according to the mode of collection and other local details.

The main questions to be considered in connection with this subject may be dealt with under two heads, viz. :—

1. The means of temporary storage on premises pending "collection."

2. The different methods of collection.

Storage.—To comply with the requirements of modern sanitation it is necessary that the accumulations of refuse at the occupier's premises be as small as possible, and that there should be frequent removals. To meet this demand there is nothing better than the portable galvanised iron pail with tight-fitting cover, sufficient to hold a collection not exceeding one week's refuse. In many parts of a town, where there is very little open space in the rear, a daily collection of refuse is often found to be necessary on sanitary grounds.

Brick or fixed ash-pits are very undesirable, frequently become a nuisance, and should be abolished wherever possible.

Collection.—With regard to the different methods of collection, whilst it is impossible to lay down any one system as being suitable to all towns, generally speaking, the following systems, or some modification of them, are those usually adopted :—

The Portable Iron Pail System.—By this method the refuse is deposited in small portable pails placed in front of the premises for removal by the scavengers as they pass through the streets on their rounds at certain fixed intervals. This method is an expeditious and economical one so far as the carrying out of the work is concerned, as it saves a good deal of time owing to the fact of the scavengers not having to enter upon the premises to carry out the refuse. An objection is often raised in the better class residential streets, and where there is shop property, to the display of dust receptacles (of great variety in design) for an uncertain period of time in the front forecourts or gardens of houses. On sanitary and economical grounds the method is a good one, but these are frequently outweighed by other considerations often more or less sentimental.

The "Bell Cart" System.—In this the carts pass through the streets and a bell attached to the horses warns the householders to bring out their refuse. As a matter of fact occupiers often bring the refuse out before the cart arrives, and it thus becomes blown about or upset by dogs or mischievous boys. The noise of the bell is also objected to by many.

The "D Cart" System consists in the occupier placing a card bearing the letter D in large type in the window when a call from the scavenger is required. The object of the card is to save time on the rounds of the collectors by enabling the men to avoid making needless calls. This is not a good method, on sanitary grounds.

Calling on Receipt of Notice from the occupier has been adopted, but the plan is a bad one, as on the neglect of the occupier a large and objectionable accumulation of refuse may arise. The amount of manual and team labour required from day to day is also an uncertain and variable quantity, and therefore very difficult to organise.

Periodical Collection from house-to-house at fixed intervals without notice is a better plan, and more certain and satisfactory in its results, but the time occupied—and hence the cost—will be greater.

Collection from Public Dust Bins fixed by the local authority in suitable positions in order that householders in their immediate locality can place their refuse into them—their clearance being effected by the authority as necessary. This system is found useful in the poorer and more densely populated parts of some towns, but the placing of the bins so as to avoid objections is a difficult matter.

Dust and Scavenging Carts.—These should be sanitary tip-carts or vans, with sliding iron covers, removable in sections, similar, for example, to the "Champion" dust van of the London County Council pattern made by Messrs. Glover, of Warwick.

The principal points to be kept in view in organising a proper system of house refuse collection are as follows :—

1. The collections must be frequent so as to admit only of small accumulations, thus producing the maximum of benefit to the public health.

2. A thoroughly systematic and regular daily routine must be adhered to, so that householders may know as precisely as is possible when the scavengers will appear, thereby giving rise to the minimum of inconvenience to the public, and inducing their fuller co-operation, which will considerably facilitate the work of collection.

3. There should be an inspector whose duty should consist of making house-to-house visits to see that all refuse is properly removed, to supervise the collectors when on their rounds, and to attend promptly to any complaints.

4. Householders should be well informed as to what is house refuse, and as much garden, vegetable, and other organic matter as possible should be consumed or buried on the premises.

5. There should be a proper method and recognised charge per load for the removal of "trade refuse," in the absence of any definite rule providing for its free removal.

6. The work of refuse collection is essentially one in which questions of economy and efficiency must be closely studied, bearing in mind the sanitary advantages to the public health to be gained by prompt removal, especially during hot weather. W. H. M.

Refuse Destructors. (*See* "Destructors.")

Refuse Disposal.—The different kinds of "refuse" collected from towns may be described as either "house refuse," "trade refuse," "street refuse," or "garden refuse"—the first three descriptions being particularly defined by the Public Health (London) Act, 1891 (*see article* "Refuse Collection"). In most provincial towns the total amount of material collected is largely augmented during certain parts of the year by the production of considerable quantities of "garden refuse," which has an important bearing upon the question of "disposal" as well as that of "collection." Most authorities, however, find it necessary, on the ground of cost, to impose a limit upon the amount of garden and trade refuse to be removed at the public expense.

The sanitary disposal of refuse collected from human habitations is a matter of primary importance and a first step towards the building up and maintenance of a high standard of public health.

The methods of disposal selected in different districts depend largely on local conditions, but very commonly the cheapest plan available has the preference. Frequently this may be no better than a mere makeshift, and the means of disposal for many years may be nothing better than a hunting about from one makeshift to another, until, finally, other means having been exhausted, a specially-built refuse destructor (*see article* "Destructors") becomes an absolute necessity.

The chief methods employed for the disposal of the refuse collected from towns are the following:—

(1) Depositing upon waste or low-lying land, filling of pits and excavations, or raising the level of marsh land, such sites being temporarily described as "tips" or "shoots." This is a very favourite and cheap means of getting rid of the refuse, where suitable sites exist within close proximity to towns, but it cannot be considered sanitary. Refuse tipped in large quantities invariably takes fire through spontaneous combustion due to the heating of the vegetable material and garden refuse contained therein, and when once started usually continues to smoulder and smoke, causing considerable nuisance from smell in the immediate vicinity of the "tip." Such sites

are usually resorted to by the poor, by rag and bone pickers and such like, for the purpose of sorting over the material deposited day by day, and it is thus not only liable to become a centre of infection, but offers an unhealthy occupation to persons of the poorer class, amongst whom sanitary precautions are pre-eminently needful.

(2) Mixing household ashes, dust, &c., with pail excreta for the purpose of their common disposal by sale or otherwise to farmers for agricultural purposes. This method is practised in some of the northern towns where the "pail-system" for the removal of excreta is in use, but it cannot be regarded otherwise than as an offensive and insanitary business.

(3) Selling or giving away to brickmakers is a less objectionable plan, especially where the handling and picking over of the refuse is not permitted. The refuse is usually screened, and the fine ashes mixed with the brick, and forms the "firing" element, whilst the "breeze," or cinder portion, is used for firing the kilns when the bricks are in the "clamp." Present-day refuse contains, on the average, less cinder and ashes than formerly, owing to the extended use of gas fires, and the large proportion of vegetable material, paper, tins and packings of all kinds of artificial foods and preserved fruits, and such like.

(4) Mixing with sewage sludge and ploughing or digging into the soil of sewage farms. This may be done to advantage where suitable land of sufficient quantity can be obtained within a reasonable distance from the town, and yet at the same time sufficiently free from inhabited dwellings to avoid any possibility of nuisance from smell.

(5) Mixing with precipitated liquid sewage sludge, or with pressed sewage sludge-cake, and cremating in destructor furnaces. These processes have been carried out at Ealing and Leyton, and, though costly, may, in certain circumstances, prove a convenient means of riddance of two objectionable classes of materials.

(6) Crushing or pulverising the refuse by machinery and employing the resulting product as a manure or in the manufacture of fuel with an admixture of tar. Fuel briquettes are manufactured by reducing the refuse by means of a crusher to a fine uniform consistency, mixing with tar, and then passing the admixture through a briquette press. The approximate cost of a plant, including a manipulator or crusher, mixer, press, buildings, and power sufficient to deal with 10,000 tons of town refuse yearly, is about £2,500, or, say, 5*s.* per ton of refuse per annum. The fuel thus produced has an average calorific value of one-third that of the best coal.

(7) Riddling, burning the cinders and vegetable refuse to generate steam, and using the fine dust in connection with a manure manufactory, the old iron being sold, and the pots, &c., used for the foundations of roads, forms another convenient method of disposal where conditions are suitable.

(8) Selling by tender yearly is sometimes adopted where offers can be obtained, but in the majority of cases this is not possible.

(9) Barging away down canals to country districts is done by some metropolitan boroughs. Although this entails considerable expense, in many cases it proves less costly than burning in destructors.

(10) Taking out to sea in specially-built hopper barges and sinking the refuse in deep water is another means of riddance of this material. This method is followed at Liverpool, and the cost of disposal is about 1*s.* 6*d.* per ton. Care has to be exercised in selecting the time, tide, and site for discharging the refuse into the sea, as the lighter portions are very apt to float ashore and cause complaints.

(11) Utilising by "sorting" by hand or by machinery and selling the ingredients for use in such trades or manufactures as can employ them, as is done in dust contractors' yards. This cannot be considered a satisfactory mode of treatment, as it involves a good deal of handling of the refuse, and is necessarily an unhealthy operation for the workpeople employed.

(12) Destroying the crude refuse, as collected, by fire in suitably-built refuse destruc-

tors, and utilising the residual clinker and surplus steam generated by the heat of combustion for various useful purposes. Where properly carried out, this is, without doubt, the most sanitary method of disposal. The plant employed should be of the latest and most approved high temperature type, and suitable means should be provided to dispense with the handling of the refuse as far as is possible. The system involves a considerable amount of capital expenditure, and the working expenses are heavy, but where suitable conditions exist some part of the expense may come back from the sale of residuals and the use of surplus heat. (*See articles* "DESTRUCTORS" and "REFUSE COLLECTION.")

W. H. M.

Reinforced Concrete or Ferro-Concrete.

—Essential Features—Expansion and Contraction—Adhesion to Steel—Expanded Metal—Shear Stresses—Mixing Concrete—Foundations—Retaining Walls—Bridges, Sewers, &c.—Corrosion.

ESSENTIAL FEATURES.—The principle of reinforcement is that Portland cement concrete, which is very strong in compression, is used in conjunction with mild steel, which is very strong in tension, and the two are so arranged that the concrete shall take the compressive stress while the steel takes the tensile stress. The result is that the combination forms a cheap and very efficient mode of construction that may be adapted to almost every kind of structure. Fire-resisting floors composed of these materials first took the form of steel joists embedded in the lower side of a concrete slab. This was convenient because the rolled joists could rest upon the walls without any special provision to receive them, and the concrete was easily filled in between and over them. It was soon found, however, that to give sufficient covering to protect the lower flange of the joists from the action of fire a total thickness was required that was not economical, and smaller sections were adopted for the reinforcement, such as tee bars and Columbian sections, which were placed closer together. This produced a better distribution of the two materials, and a very simple investigation showed that further improvement would be obtained by using the steel in still smaller sections and placing it very near the lower surface of the concrete.

EXPANSION AND CONTRACTION.—Considerable doubt was felt at the time as to the stability of such a floor under the action of heat, owing to the popular idea that steel expanded much more than concrete under the same increase of temperature; but it was shown that their expansion and contraction were almost identical. As a matter of fact, the linear change for a given variation of temperature is about 15 % less for concrete than for steel; but when the actual figures are compared the difference is very trifling. Taking the range of temperature between summer and winter as 70° F., the change of length in 100 ft. produced by this variation of temperature will be for steel 0·546 in., and for concrete 0·464 in., the difference between the two materials in a length of 1 ft. being less than a thousandth of an inch.

ADHESION TO STEEL.—The next doubt was whether the concrete would adhere sufficiently to plain steel rods or bars to enable them to receive the full tension without drawing through the concrete, and numerous patents were obtained for bars that should have a direct hold upon the concrete, such as twisted, corrugated, indented, and stud bars. Experiment, however, showed that there was a strong adhesion between the concrete and the metal depending upon the condition of the surface of the latter and the closeness with which the former was packed against it. The best adhesion was obtained when the steel was slightly rusted all over and painted with cement wash just prior to placing the concrete. Prof. Bauschinger found the ultimate adhesion to be from 569 to 668 lbs. per square inch. The Royal Institute of British Architects recommend 100 lbs. per sq. in. as a working allowance, and at this figure the embedded length of steel that would leave the tensile

strength and adhesion equal would be equal to 16,000 times the sectional area of the bar in square inches divided by 100 times the surface area per inch in length, or briefly $160\frac{a}{s}$, so that a $\frac{1}{2}$ in. square bar embedded for a length of not less than 20 in. in either direction from a given point, would be equally strong against tearing or slipping, and similarly a 1 in. round bar would need to be embedded for a length of 40 in. In other words, 40 times the diameter in inches gives the requisite overlap or length for embedding any plain round or square bar to be equally strong against tearing or slipping; the smaller the rods the larger the proportionate surface for a given length.

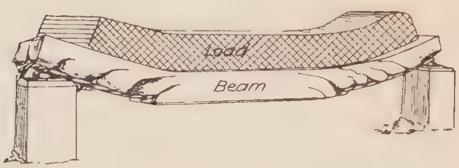


FIG. 1.—Loaded Beam failing by Shear.

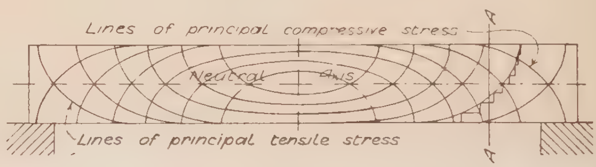


FIG. 2.—Curves of Stress in Beam.

EXPANDED METAL.—The reduction in size of the rods naturally led at an early date to the substitution of wire in the form of rectangular netting; but expanded metal with lozenge-shaped openings soon received more favour than the netting, and is now largely used. Over the supports it is kept near the upper surface of the concrete, and droops in the centre of the span to be near the lower surface; but it does not permit of the close approximation of the stresses that is given by rod construction with shear members.

SHEAR STRESSES.—This leads to consideration of another difficulty which arose in the early designs. Everybody was aware of the direct stresses of compression and tension in the upper and lower sides of the beams and how to calculate them approximately, but they overlooked the shear stress that is a necessary accompaniment, and it was not until failures took place by diagonal cracks near the ends of the beams, as in Fig. 1, that attention was called to the need of providing specially for the shear stress. The first and most obvious means of doing this was by turning up some of the tension bars diagonally at the outer ends. Where four bars were required in the centre, only two were wanted beyond the middle third of the span; but the four were there, so they were bent up to take this other duty. This was only a crude method and not altogether sufficient. Then various forms of stirrups, vertical or inclined, were introduced in connection with the longitudinal bars, placed closer together towards the ends where the shear stress was greater. These were at first put in loose, and then the Kahn bar was introduced. This consisted of a square bar placed diagonally with longitudinal fins or webs projecting on each side which were sheared at intervals and bent upwards at an angle of 45°. Then various forms of shear rods were introduced twisted tightly on to the main rods at such intervals as were necessary exactly to meet the shear stresses, such as the twisted "Paragon" wires of the British Reinforced Concrete Engineering Co. The actual stresses in a beam may be represented by the curves in Fig. 2. Usually the stresses are treated as if they were simply longitudinal and transverse, the former being tension and compression and the latter shear. They can, of course, be met in this way by suitable reinforcement; but it should be remembered that the shear to be resisted in a ferro-concrete beam is more in the nature of a diagonal tension, and should be provided for by diagonal reinforcement. While these modifications were going on it was found that further economy might be obtained by making the floor slabs "continuous" over the beams, and the beams "continuous" over the columns; this caused reverse stresses over the supports

and necessitated the inversion of the system, which was a comparatively simple matter, additional longitudinal bars being put near the upper surface over the supports with the shear bars projecting downwards.

When this system of construction was adopted for the walls of the buildings the floor slabs and beams were connected to them in the same way as if the wall was one side of an intermediate support, and this made the connection equivalent to "fixed ends" in girder work.

Mixing Concrete.—For all reinforced concrete work it is essential that the utmost care should be taken in mixing and placing the concrete. For thin slabs the usual proportion is one part of standard Portland cement by measure to two parts of clean, coarse sand, and four parts of larger aggregate. Before the days of reinforced concrete it was considered sufficient if the aggregate was broken to pass a $1\frac{1}{2}$ in. ring, and for this new purpose it was reduced to a uniform gauge of 1 in. Now the material is generally specified to range from $\frac{1}{4}$ in. to $\frac{3}{4}$ in., the varying size being necessary to enable it to pack closely. For fire-resisting floors the best material for the aggregate is hard brick broken as stated, but coke breeze has many advocates. Broken pumice stone makes a light floor, but has a low crushing strength, while broken limestone calcines and loses its strength entirely, and flint pebbles burst under the action of heat; but both these materials are suitable in foundations. Clinker may contain free lime and cause disruption by delayed slaking. The steel is usually in the form of round rods of mild steel from $\frac{1}{2}$ in. to 1 in. diameter, having an ultimate tensile strength of from 29 to 32 tons per square inch, and a modulus of elasticity of about 29 million pounds, or 13,000 tons. The elongation of a test piece is about 20 % in a length of 8 in., with a contraction of area at point of fracture of about 40 %

Arrangement of Building.—The general arrangement of a ferro-concrete building is somewhat as follows:—First, the foundations are made wide enough to spread the

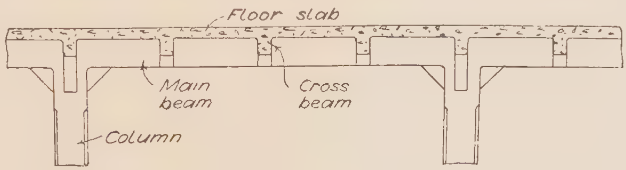


Fig. 3.—General Type of Floor Section.

load over a sufficient area of the subsoil to avoid risk of settlement, being wider where the piers will be placed to support the floor and roof beams. Instead of the thick mass of concrete seen in ordinary foundations, only about one-third of this thickness is required

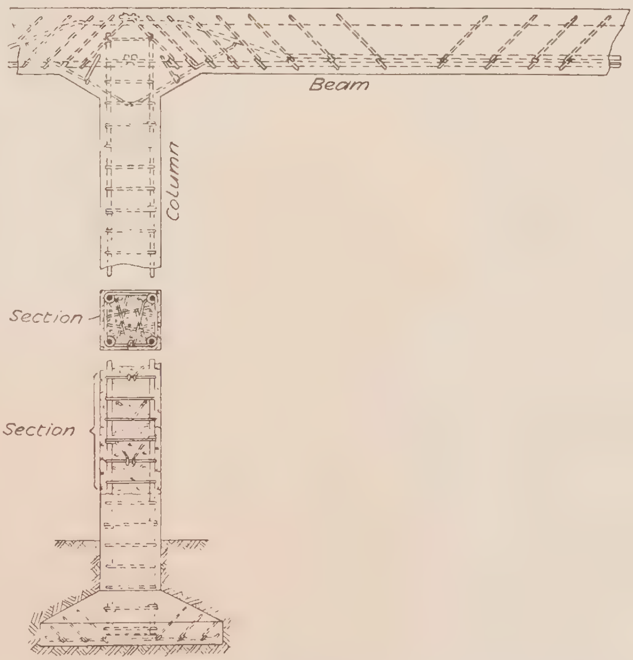


Fig. 4.—Section through Floor and Column showing Reinforcement.

in the case of ferro-concrete, the side wings, as they may be called, of the foundations being strengthened so that they act as

cantilevers. Then the walls, instead of being uniform in thickness, consist of piers and panels, the piers to carry the weight of the floors and roof, and the panels merely to form a screen from pier to pier. Reinforcing rods are embedded throughout. At each floor ferro-concrete beams are built across the room from pier to pier with cross-beams in

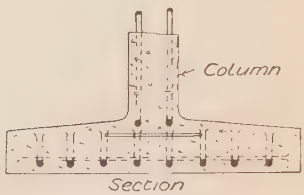


Fig. 5—Section through Foundation of Column.

the case of large spans, and then floor slabs to form the filling between the beams. In a few cases the roofs are also constructed in a similar manner with flat or sloping tops. The work is not finished off a piece at once, but the rods and connections are put in place considerably in advance of the concrete, and timber "forms" are built up to give the

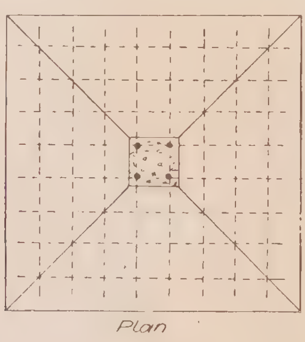


Fig. 6.—Plan of Foundation of Column.

required external dimensions to the concrete. The concrete is then put in place in small quantities, packed round the rods and connections, and gently rammed. This description is sufficient to give a general idea of the mode of construction usually adopted, and some of the details are shown in the illustrations. Fig. 3 shows a typical section of a ferro-concrete floor, consisting of main beams, cross beams, and floor slab supported on columns. All junctions are made gradually by 45° gusset pieces or fillets, and this gives an interior very much the appearance of heavy timbering, especially as the grain of the wood used in supporting the concrete sometimes shows on the face of the latter. Fig. 4 shows a larger

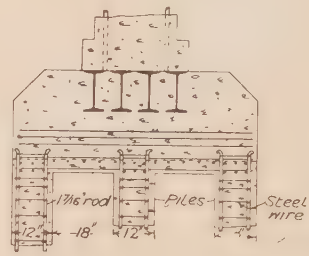


Fig. 7.—Section of Heavy Foundation.

section through a column and floor beam with the Paragon shear stirrups twisted firmly on the reinforcing bars. In the column the bars are prevented from spreading by encircling wires, every fourth wire being twisted round each of the bars. The lower part of this figure shows a common form of

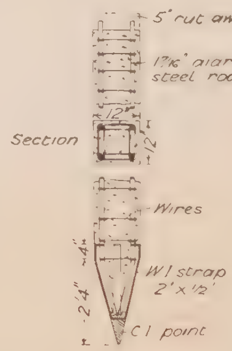


Fig. 8.—Ferro-Concrete Pile.

reinforced base for spreading the load carried by the columns.

Foundations. — Fig. 5, elevation, and Fig. 6, plan, shows more fully how such a foundation is constructed, the shear stirrups here being placed vertically in the Hennibique manner. When bad soil has to be contended with, and particularly where very heavy loads

have to be carried, the foundation is more elaborate, as in Fig. 7, the load being spread by rolled joists over the reinforced concrete, and this in turn supported by ferro-concrete piles. Fig. 8 shows the detail of a pile. The lower end is shod similarly to a timber pile,

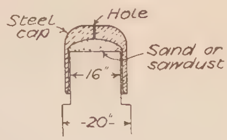


Fig. 9.—Steel Cap for Driving Pile.

the shoe having a cast point and wrought straps; but the upper ends of the straps are bent inwards and embedded in the concrete to keep them in place. The piles are driven by an ordinary pile engine, or better by a Lacour steam driver; but the top needs some protection to prevent it from being broken up by the falling ram. Sometimes a wooden

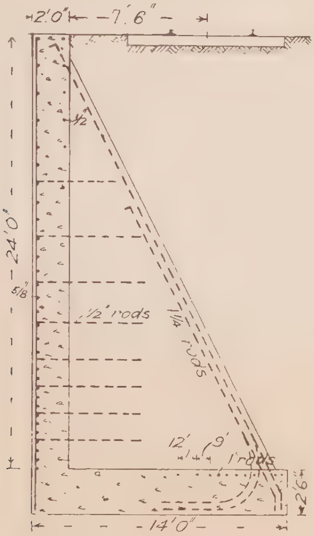


Fig. 10.—Section of Retaining Wall with Counterforts.

dolly is interposed. The more general method is, however, to place upon it a steel cap, as Fig. 9, with sand or sawdust in it to distribute the blow. To drive any pile, and particularly a concrete pile, with the least resistance, it is important to keep it on the move; and this is the advantage of the steam driver in giving a rapid succession of blows, not leaving time for the soil to settle against the faces of the pile. After driving, 5 in. or 6 in. of the concrete is cut away from the top

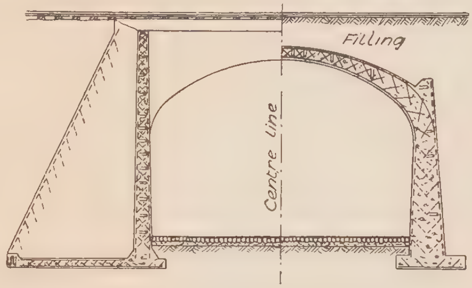


Fig. 11.—Sections through Bridge and Wing Wall.

to enable the steel rods to be bonded with the superstructure.

Retaining Walls.—Perhaps the greatest departure from past methods of construction occurs in the new form for retaining walls. Hitherto they have been designed to resist thrust and overturning simply by their mass; now they practically have no mass and rely for

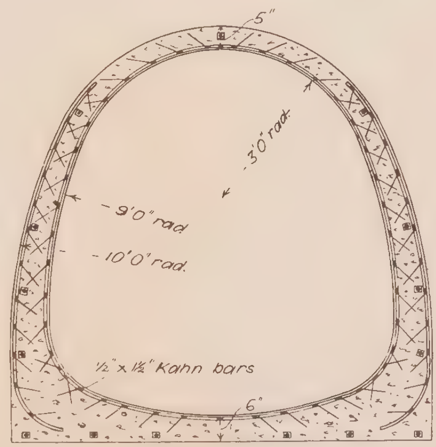


Fig. 12.—Section through Large Sewer.

stability upon their strength being utilised in carrying the mass they have to support. Fig. 10 shows a typical wall with base and counterforts. The earth that is to be held up rests upon this base so that the wall cannot tilt without lifting it, and it thus becomes a main element of the stability. The effect of the counterforts is

solely to connect the base to the vertical wall; some walls have them omitted, and on two of the American railroads plain L and T sections are largely adopted; but the omission of the counterforts must greatly increase the risk of failure of the walls owing to the excessive stress caused at the junction between wall and base.

Bridges, Sewers, &c. — Ferro-concrete bridges of widely different design and span have been constructed, and no definite type has yet been determined to be the best. Some of the early ones were very ugly; but numerous bridges of good architectural elevation have now been erected. Fig. 11 shows a plain railway bridge with abutments and wing walls. The construction is very simple and self-evident. The reinforcing bars are placed in two sets, near the inner and outer surfaces of the arch, those on the inner face are doubled in the centre of span, and those on the outer face are doubled from the haunches to the abutments.

Fig. 12 shows the section of a large concrete sewer reinforced on the Kahn system. This type of sewer construction has been very largely used in America and is applicable to culverts, tunnels, conduits, and subways. The details are of course modified according to the nature of the soil passed through. The finest illustration of ferro-concrete construction is, perhaps, given by the Marlborough Blenheim Hotel, Atlantic City, N. J. The front portion of this building is twelve storeys high, surmounted with a dome, 30 ft. diameter. The entire structure is built of reinforced concrete on the Kahn system, and shows that with care considerable architectural effect can be obtained.

Corrosion.—The Science Committee of the Concrete Institute has under consideration at the present time various important details connected with this form of construction, among which may be mentioned the standardisation of formulæ and notation; the conditions under which embedded steel may corrode; the characteristics and mode of using various aggregates; the supporting power of concrete piles; the waterproofing of concrete, &c. It is now generally conceded that the best protection for the steel is to let it get slightly rusted, then to brush it all over with a wire brush sufficiently to remove any loose rust, and paint it with a wash of Portland cement before embedding it in the concrete. Treated in this manner, it has been found bright after some years although only a short distance from the face of concrete exposed to the action of sea water. Where any corrosion has occurred it has been found to be due to cracks permitting of direct access from the outside, or to the action of sulphur contained in the aggregate. As an instance of the protection afforded to the metal by the concrete, some reinforced concrete waterpipes ($1\frac{3}{8}$ in. thick) were constructed in Grenoble 22 years ago. After 15 years, two lengths of pipe were raised for inspection, and it was found that although the water had been flowing through them and they had been embedded in soil for all those years with only $\frac{3}{8}$ in. of Portland cement concrete protecting the steel, the metal was as bright as on the day it had been put in.

H. A.

Retaining Walls are strong walls of masonry, brickwork, or concrete, built at the side of an excavation to support the adjacent earth and resist its thrust, such as those round a sunk reservoir or dock, at the sides of an urban railway cutting, or on a sea front or canal. The thrust is the primary element for consideration; it varies with the nature of the soil and the difference of its level on the two sides of the wall. A heap of earth left to itself will in course of time weather down to an angle with the horizontal called its angle of repose or natural slope, varying generally between 25° and 45°, as in the following tables.

Rankine, ϕ =

Dry sand clay and mixed earth	37 to 21
Damp clay	45
Wet clay	17 to 14
Shingle and Gravel . .	48 to 35
Peat	45 to 14

Unwin, $\phi =$

Fine dry sand	37 to 31
Sand, wet	26
,, very wet	32
Vegetable earth, dry	29
,, ,, moist	49 to 45
,, ,, very wet	17
,, ,, consolidated and dry	49
Loamy earth	40
Clay, dry	29
,, damp, well drained	45
,, wet	16
Gravel, clean	48
,, with sand	26
Loose shingle	39

Molesworth, $\phi =$

Gravel average	40
Dry sand	38
Sand	22
Vegetable earth	28
Compact earth	50
Shingle	39
Rubble	45
Clay, well drained	45
,, wet	16

Author's Practice, $\phi =$

Wet sand, clay or vegetable earth	15
Dry sand, clay or vegetable earth	30
Loamy earth, loose shingle, clay well drained	40
Firm gravel and hard dry vegetable earth	45

If the earth were left without support and with a vertical face, it is assumed that the first failure would be the breaking away of a wedge of earth contained between the vertical face and the bisection of the angle between the vertical and the line of natural slope, called the line of rupture, indicated by the shaded portion in Fig. 1. It is this wedge of earth that the retaining wall has to support, and the wedge action due to its shape and weight causes a tendency to slide down the line of rupture and produce a horizontal thrust against the back of the retaining wall, increasing uniformly in intensity from the top to the bottom, with the centre of pressure at one-third the height, as shown at P in Fig. 2, which shows the section of an ordinary retaining wall. The wall is so designed that its weight combined in a parallelogram of forces with the thrust of the earth shall give a resultant passing through the base at one-third of its thickness from the outer edge. This produces a distribution of the reacting forces in the foundation shown by the triangle below the wall, with a maximum compression at the outer edge, reduced to nothing at the back. Then the moments of the forces in action will be equal, $Px = Wy$. When the resultant falls within the middle third of the base it means no more than that there will be no tension on the inner edge of the base. It is generally supposed that under these conditions any wall will be safe, but this is not necessarily the case. With a high wall its weight may increase the compressive stress beyond the safe limit, and with a low wall it is often possible to be within safe limits when the resultant is only one-fourth of the thickness from the outer edge. The thrust of the earth may be found entirely by calculation, or partly by calculation and partly by graphical construction. By calculation the formula is $T = \frac{1}{2}\, wh^2 \tan^2\left(\frac{90 - \phi}{2}\right)$, or, the same thing in another shape, $T = \frac{1}{2}\, wh^2 \frac{1 - \sin\phi}{1 + \sin\phi}$, where $T =$ horizontal thrust in lbs., $w =$ weight of earth in lbs. per cubic foot, $h =$ height in feet, $\phi =$ angle of natural slope in degrees. The second method is to deal with 1 ft. run of this wall and earth, mark the centre of gravity of the wedge of earth as in Fig. 3, and drop a vertical line to cut the line of rupture. Calculate the weight of the wedge of earth and set the amount up to scale from the intersection with the line of rupture, from which point also draw a horizontal line, and from the upper end of the marked amount draw a line parallel with the line of rupture. This will cut off a horizontal distance equal to the total thrust

measured with the same scale. The centre of gravity of the wall is then found by setting off the width of base on each side of the top, and the width of top on each side of the base, and drawing diagonal lines which will intersect at the centre of gravity of the wall. Then transferring the thrust in the same horizontal line beyond the centre of gravity of the wall and setting off the weight of 1 ft. run of the wall to the same scale below it, the parallelogram is completed and the resultant produced to cut the base. Wherever the resultant cuts the base, if tension may be allowed, the formula

FIG. 1.

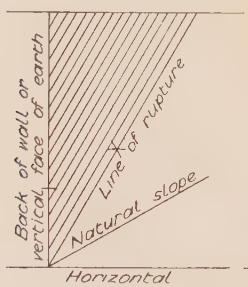


FIG. 2.

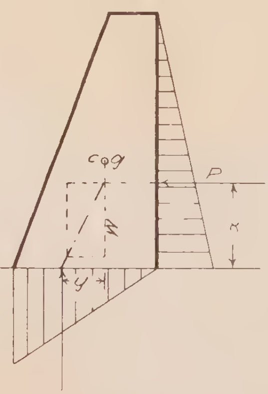


FIG. 3.

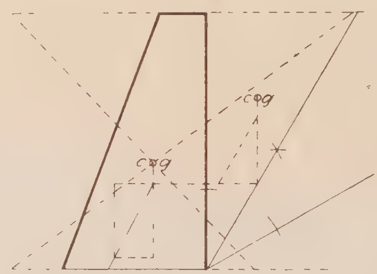


FIG. 1.—Wedge of Earth pressing against Wall. FIG. 2.—Distribution of Pressures on Wall.
FIG. 3.—To find Stability of Wall.

for the stress at outer and inner edges will be $\frac{W}{A} \pm \frac{M}{Z}$, where W = weight of 1 ft. run of wall in lbs., cwts., or tons, A = sectional area of base in square feet = thickness × 1 ft., M = bending moment = weight of wall × distance in feet from centre of base to point where the resultant cuts it, Z = section modulus of base = $\frac{1}{6}$ of the width of base in feet squared. The + value gives the compression per square foot at outer edge and the — value gives the compression or tension, as the case may be, per square foot at the inner edge. When no tension can be allowed this formula will apply so long as the resultant does not pass beyond the middle third, but if it passes beyond this the formula for the compression at outer edge will be $\frac{2}{3} \times \frac{W}{d}$, where W = weight of wall and d = distance of resultant from outer edge of base. It will be self-evident from Fig. 2 that a wall of the section shown will be more efficient than an upright wall of parallel thickness, as, owing to the battering face, the centre of gravity is thrown further back and the weight acts with a greater leverage. The usual batter varies from 1 to 3 in. per foot according to circumstances, and the courses of the brickwork or masonry are always laid at right angles to the face. The back of the wall is usually stepped in half-brick ($4\frac{1}{2}$ in.) set-offs, at such intervals that the mean line is vertical, and the top is surmounted by a stone coping, or blue bricks on edge laid in cement mortar. From three to six courses of footings are usually carried out beyond the face of the wall but none on the back, and the wall is usually built on a cement concrete foundation, thicker at the front than the back, in order that the under-side may be level. The earth filled in at the back of the wall must be punned in 1 ft. layers inclined away from the wall to reduce the tendency to slip, and if there is an existing bank to the earth it must be benched, or cut in steps, before the filling-in takes place.

When the wall has earth on one side and nothing on the other, provision must be made for carrying off any water that may collect behind it by forming vertical rubble walls. A complete design for a retaining wall is shown in Fig. 4. A wall to resist the pressure of water may be designed upon exactly the same principles, bearing in mind

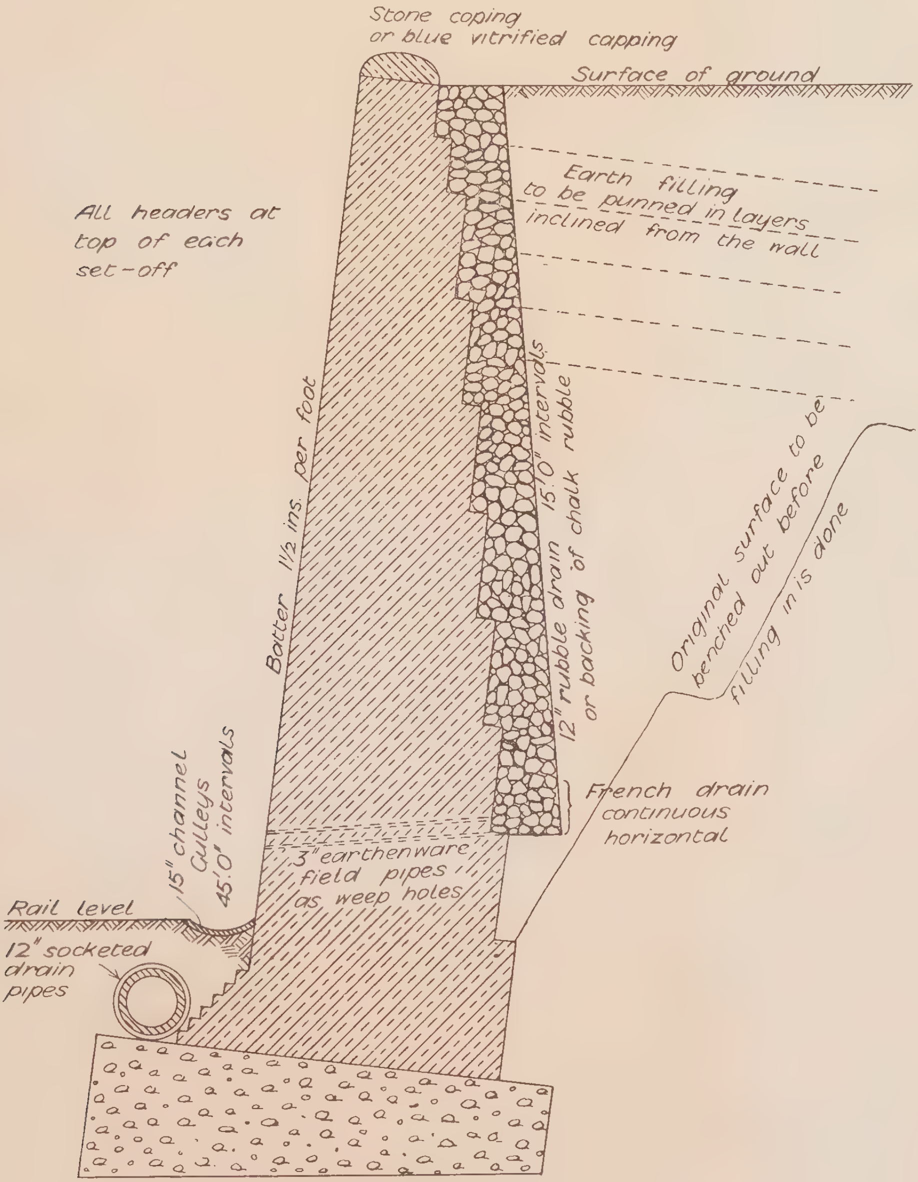


Fig. 4.—Complete Design for Retaining Wall.

drains at intervals of 10 or 12 ft. with weep holes near the bottom, and connecting them by a horizontal French drain. This will not be required in the case of reservoir or dock that the natural slope of water is nil and that the assumed line of rupture will therefore be at 45°. When there is earth on one side of a wall and water on the other, the thrust from

each must be worked out and both resultants should generally fall within the middle third of the base, but the actual stresses should be calculated in every case. The triangle from which the thrust is scaled in Fig. 3 may be set off in another way, which is rather more convenient, as it applies equally to walls with sloping backs, battering or overhanging. In Fig. 5 is shown a concrete tank wall, with the excavated material banked against the outside, and the thrust triangle drawn by setting up the weight of wedge vertically above one-third of the height, drawing a line at right angles to the back of wall for the direction of the thrust, and then setting off the angle of the wedge $\frac{1}{2}(90 - \phi)$ to complete the triangle. Any division wall in the tank, unless perforated and used as a strut only, must be sufficiently thick to resist the full pressure of water on one side of it while empty on the other, as in Fig. 6. Having drawn graphically the forces and their resultants, the stresses would be calculated as follows. In Fig. 5 the stresses due to the thrust of earth only will be $\frac{W}{A} \pm \frac{M}{Z} = \frac{4320}{4} \pm \frac{4320 \times \frac{1}{2}}{\frac{1}{6}(1 \times 4^2)} = 1080 \pm 810 =$ 1,890 lbs., or 0·85 ton per square foot compression at A, and 270 lbs. or 0·12 ton per square foot compression at B. From the combined thrusts of earth and water the stresses will be $\frac{W}{A} \pm \frac{M}{Z} = \frac{4800}{4} \pm \frac{4800 \times 1{\cdot}5}{\frac{1}{6}(1 \times 4^2)} =$ $1200 \pm 2700 =$ 3,900 lbs. or 1·74 tons per square foot compression at B, and 1,500 lbs. or 0·67 ton per square foot tension at A. In the case of the division wall Fig. 6, the stresses will be $\frac{W}{A} \pm \frac{M}{Z} = \frac{6280}{6} \pm \frac{6280 \times 1{\cdot}5}{\frac{1}{6}(1 \times 6^2)}$ $= 1046 \pm 1570 =$ 2,616 lbs. or 1·66 tons per square foot compression at C and 524 lbs. or 0·24 ton per square foot at D. It will therefore be evident that the walls might have been reduced in thickness probably by 6 in. When a retaining wall supports a bank of earth sloping upwards above its own height, it is said to be surcharged, and the thrust is greatly increased. The simplest way of finding the thrust is by using Rankine's graphic method shown in Fig. 7, and worked as follows:—Let $A\ B\ C\ D$ be the section of the proposed wall, $D\ E$ the line of surcharge, the natural slope and line of rupture being drawn as usual. Then set up $B\ F$ making angle ϕ with back of wall, produce $E\ D$ to F, bisect

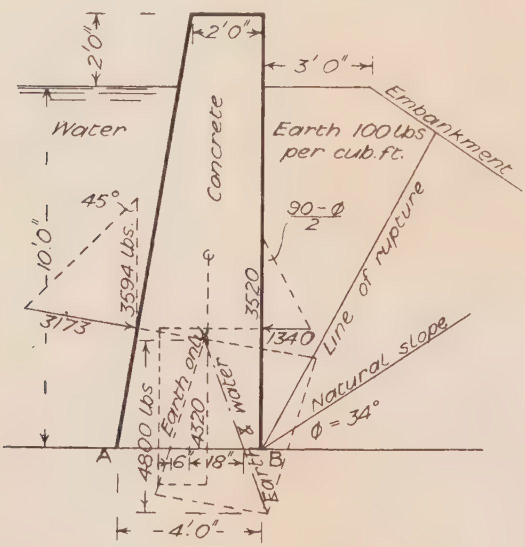


Fig. 5.—Concrete Tank Wall.

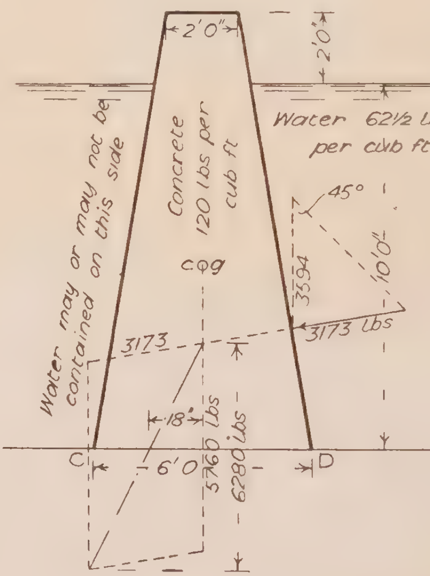


Fig. 6.—Concrete Division Wall in Tank.

$B F$ in G, and from G as centre draw the semicircle $B F$. From D drop a perpendicular

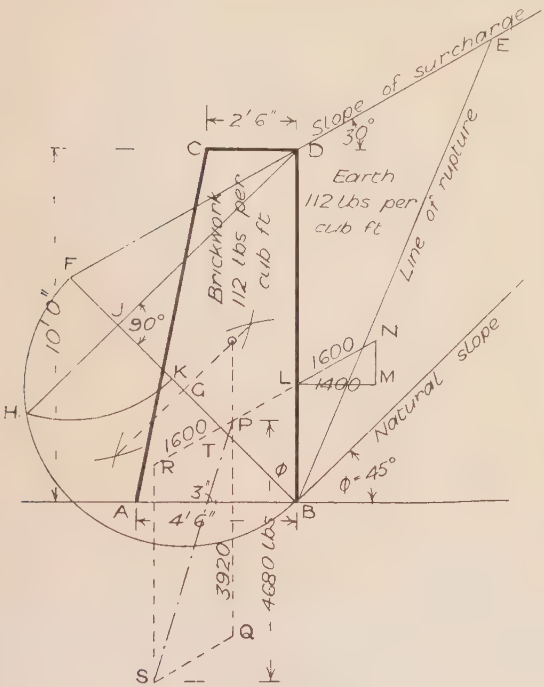


Fig. 7.—Surcharged Retaining Wall.

on to $B F$ cutting it in J, and continue $D J$ through to H. From centre F, with radius $F H$, cut $B F$ in K. Then the horizontal thrust will be found by the formula $T = \frac{1}{2} w (B K)^2 = \frac{1}{2} \times 112 \times 5^2 = 1{,}400$ lbs. acting at one-third of the height as shown at $M L$. Draw $L N$ parallel with the line of surcharge, and cut it off by the vertical $M N$, then $N L$ gives the actual thrust against the wall. Drop a line through the centre of gravity of the wall, and produce $N L$ to intersect it in P; then $P R =$ thrust, and $P Q =$ weight of wall, the resultant $P S$ cuts the base at T, 3 in. from centre of base, the vertical component being 4,680 lbs. Then the maximum stresses will be $\frac{W}{A} \pm \frac{M}{Z} = \frac{4680}{4\cdot5} \pm \frac{4680 \times \frac{1}{4}}{\frac{1}{6}(1 \times 4\cdot5^2)}$ $= 1040 \pm 347 = 1{,}387$ lbs. or 0·62 ton per square foot compression at A, and 693 lbs. or 0·31 ton per square foot compression at B. The maximum safe load on brickwork being from 3 to 10 tons per square foot, according to quality, there is an ample margin of safety, but if the wall is reduced in thickness the maximum stress will rapidly increase, so that it may be left as given. When the slope of surcharge is parallel to natural slope, $B K = B F$. When the earth at the back of a retaining wall is loaded in any way, some allowance must be made for the increased thrust produced against the wall. There is no generally recognised method of doing this, but the following is put forward as a reasonable suggestion for the purpose. Let two loads be carried as in Fig. 8, $W_1 = 1$ ton per foot run, $W_2 = 4$ tons per foot run, at distances of 2 ft. and 3 ft. from back of wall. From the point of application of the load W_1 draw a line parallel to the line of rupture to cut the back of the wall, and assume this to be the point of application of

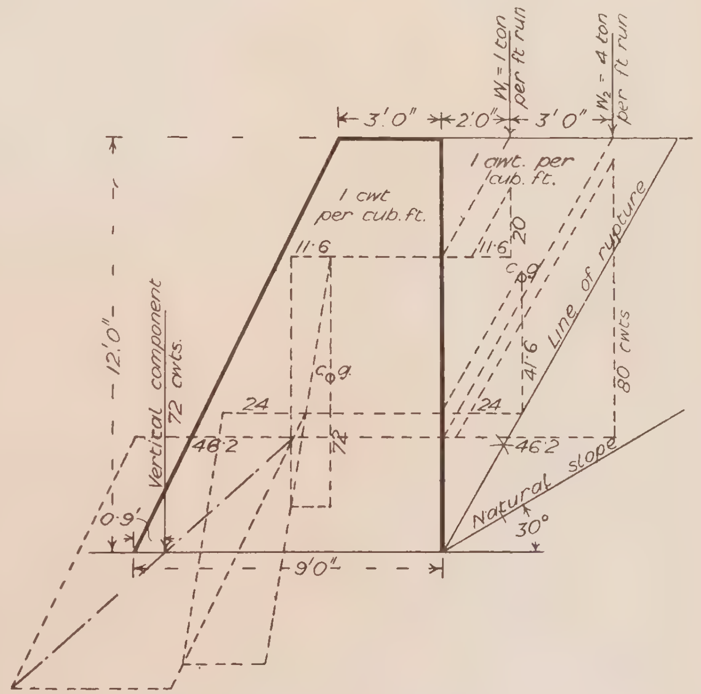


Fig. 8.—Wall Loaded at Back

the thrust from this load, the value being found by triangle in the ordinary way. Combine this thrust with the weight of the wall, and draw the resultant. Combine this resultant with the thrust due to the weight of the wedge of earth and draw the second resultant; then combine this resultant with the thrust from load W_2, found as above described, to give the final resultant cutting the base as shown. Then the vertical component of the final resultant being 72 cwts. and the point of intersection with the base

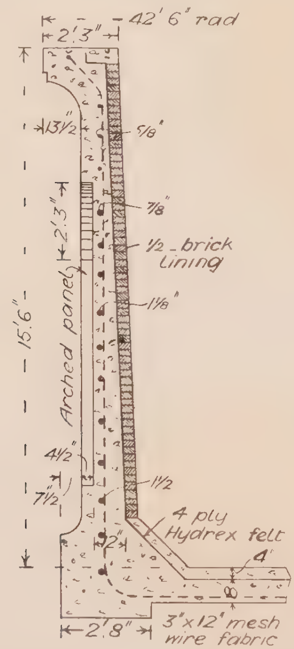


FIG. 9.—Ferro-Concrete Retaining Wall.

0·9 ft. from the toe of wall, the maximum compression will be $\frac{2}{3}\frac{W}{d} = \frac{2}{3} \times \frac{72}{0·9} = 53\frac{1}{3}$ cwts. $= 2\frac{2}{3}$ tons per square foot. When a reservoir is built above the surface of the ground, the containing wall may be very much lightened if built in reinforced concrete. Fig. 9 shows a section through the 600,000 gallon reinforced concrete reservoir, 80 ft. diameter and 15 ft. deep, constructed at Cos Cob, Conn., U.S.A. It is founded on solid rock and is without any surrounding fill, thus making some exterior embellishment very desirable. Accordingly the wall was designed with a cornice and a slightly projecting base, and the flat belt between was relieved with a series of arched indented panels, 40 in number, giving somewhat the effect of an arcade. The concrete wall has a 4-in. lining of brick laid in cement mortar to protect the waterproofing coat. It is reinforced circumferentially with steel cable, varying in diameter from $1\frac{1}{2}$ in. at the base to $\frac{5}{8}$ in. at the top, forming a continuous spiral with 12-ft. splices made with 16 Crosby clips where the ends of two sizes of cable are joined. The pitch of the spiral varies somewhat as indicated on the drawing, but is in general about 1 ft. Inside the cable spiral is a continuous sheet of 3 in. by 12 in. mesh Clinton wire fabric, placed in vertical strips which extend 6 ft. into the floor foundation. About 10 days after the filling of the wall-forms had been completed the forms were removed and the derrick was taken out of the tank. The floor was then concreted to an even surface, and a 4-ply waterproofing coat of Hydrex felt was applied to the inner surface of the wall in vertical strips and to the tank floor. Hydrex compound was used to cement the layers of felt together. A 4 in. protective covering of concrete was laid over the floor of the reservoir on the waterproofing coat and extending a little way up the side to give a footing for the 4 in. brick wall lining. The bricks were laid with cement mortar with a solid backing of mortar between brick and waterproofing. H. A.

Richmond Sewage Disposal System.—The method of treatment at the Richmond Main Sewerage Board's works at Mortlake consists of chemical precipitation, filtration through beds of gravel and sand, and reduction of sludge by filter presses. There are eleven precipitation tanks, each 100 ft. by 30 ft. by 7ft. 6 in. deep, the total capacity being 1,210,000 gallons. These tanks can be worked either on the intermittent or continuous flow system. The effluent is further dealt with on eight filter beds, four high and four low-level beds, each 107 ft. by 100 ft. The filtering

material averages 3 ft. 6 in. deep, and consists of a layer of 9 in. pipes overlaid by gravel and sand of graduated sizes, finished with 3 in. of loam, and sown down with grass. The filters have been in use for some years with occasional renovation of the surface soil. The board's engineer, Mr. W. Fairley, A.M.I.C.E., states that the process of precipitation consists of, first, a small dose of carbolic acid and iron salts mixed with the sewage as it enters the pump well. After being pumped the sewage receives about 4 or 5 grains per gallon of milk of lime and 7 grains per gallon of a mixture of sulphate of alumina, iron, &c. The tank liquor is then passed through the filters, from the outlets of which it is discharged on the ebb tide into the Thames. The expense of chemicals per million gallons varies from 22*s.* to 25*s.*

Rising Mains.—Rising mains are laid in cast-iron pipes with a thickness of metal suited to the pressure to be withstood. They should be in as direct a line as possible, with the least possible number of bends, and should be of ample diameter to pass the volume of water required without creating undue loss from friction in forcing the water through them. In deciding upon the internal diameter it should be remembered that most probably in the course of a few years the discharging capacity of the pipes will become considerably reduced from incrustation, in which case a large increase of head may be thrown upon the pumping engines. The question of size is one which requires very careful consideration, as every additional inch in diameter involves a material increase in weight of metal in a long pipe line, whilst the error of providing too small a main results in a larger coal bill to be paid annually owing to the machinery having to work against a head partly due to the increased frictional resistance. The interest upon the additional capital outlay involved by a main of larger diameter, or on the cost of duplicating a main which may have become insufficient for present requirements, must therefore be set against the estimated annual reduction of coal bill which would result from the provision of increased main capacity, the pumping engines having to develop less power to raise the same quantity of water. Where the mains are of ample capacity the extra head due to friction will not exceed about 20 ft. per mile. The incrustation in a main often occurs, not as a uniform coating around its internal surface, but in numerous irregular nodules or lumps, thus greatly retarding the flow. The nature of the incrustation will of course depend greatly upon the character of the water pumped. For economical working the velocity of flow through the main should not exceed from 2½ to 3 ft. per second or the friction will be greatly increased. The calculations for engine power and main capacity in connection with the recent Coolgardie water scheme were based on an assumed flow of about 2 ft. per second through a pipe 30 in. in diameter. The frictional effect of increase of velocity in a main is shown by the following comparison of velocities in a clean 12 in. pipe:—A velocity of 3 ft. per second gives a frictional head of a little over 3 ft. per 1,000 ft. of length, whilst a velocity of 5 ft. gives a head of 8·5 ft. per 1,000 ft. The frictional resistance in a pipe increases in the proportion of the square of the velocity of flow, and it is thus readily seen that a very material waste of power may arise from this cause. In the same way a great loss of "head," due to insufficient main capacity, occurs in the mains of a distributing system.

On long lines of rising main of considerable head, reflux valves should be inserted at suitable intervals in order that the pumps may be relieved of pressure, and, in the event of a burst pipe, one section of the main only will be discharged to waste, and that under a much reduced head or pressure. A relief or safety valve should also be provided in the delivery pipe close to the air vessel, and should be weighted a little above the usual working pressure so as to give relief in the pipes in case of stoppage therein.

Rivers Boards: Central Authority.—As a result of the Sewage Commission of 1869, the first central authority having control over river purification was established, viz., the Local Government Board. The Public Health Act Amendment Act of 1875 stipulated that the Local Government Board should only sanction the raising of loans for sewage disposal after the schemes had been favourably reported upon by an inspector of that Board, who had held a local inquiry. The control exercised by the Local Government Board has been mainly confined to criticism of schemes thus brought before them. The Mersey and Irwell Joint Committee was formed in 1891 as a result of a petition from the county councils of Lancashire and Cheshire, and obtained special powers under the Mersey and Irwell Act, 1892. A similar committee, the West Riding Rivers Board, was appointed by Provisional Order in 1893, followed by the West Riding of Yorkshire Rivers Act in 1894. The function of these boards and others of a similar character, such as the Ribble Joint Committee, is mainly administrative, their chief activity being directed to see that local authorities and manufacturers duly carry out the provisions of the Rivers Pollution Acts in their respective districts. Although the inspectors of these rivers boards in their personal character are often very helpful to authorities by indicating measures which may properly be taken in certain cases, the Board takes no responsibility officially for such advice, for which, of course, no remuneration is given, nor are experimental investigations undertaken for other than the private information of the Board.

The Massachusetts State Board of Health, which was founded in 1886, has from the first undertaken experimental researches of great and fundamental importance. The results of these are published annually in Reports, and the officials of the Board not only examine schemes and supervise the construction of works, but also continually inspect the works in operation.

Similar State Boards have been founded in other parts of the United States, *e.g.*, Washington, New York, and Ohio.

In 1901 an Imperial Council of Health, having jurisdiction over streams, was formed in Germany by several Federal States. In the same year the question of river pollution was taken up by the Prussian Government, and the Royal Prussian Testing Institute was founded with a very extensive staff and equipment, to collect all necessary information on which the action of authorities could be based. Valuable reports are issued by the Institute from time to time.

A similar testing station has been established at the Pasteur Institute at Lille, under the direction of Professor Calmette, and very important reports have been published.

The Royal Commission on Sewage Disposal, appointed in England in 1898, has from the first advocated the formation of a central authority to deal with questions of water supply and sewage purification.

Such a central department would consist of an administrative head, assisted by highly qualified bacteriological, chemical, and engineering experts.

Among the more important questions which would have to be dealt with by such an authority would be the following:—

1. Disputes between local authorities and manufacturers as to the terms and conditions on which trade effluents should be admitted into sewers.

2. The control of shell-fish layings.

3. The protection of water supplies from pollution.

4. The collection of information as to the water supplies available in various parts of the country.

5. The collection of information as to the need of water in various parts of the country.

6. The settlement of standards for different reaches of water.

7. Conferring powers on local authorities, in suitable cases, to provide separate systems of sewers for surface water and to enforce the provision of separate drains.

8. The settlement of questions as to the

extra amount of sewage which a local authority should be required to treat during storms.

The authority would also undertake special investigations of general importance and collect and collate the work done by others, for the benefit of local authorities throughout the country. G. J. F.

Rivers Purification.—It has long been recognised that the prompt removal of human excreta from the vicinity of dwellings is one of the first essentials of sanitation. For this reason water-closets were introduced in 1810, and at first discharged into cesspools. In early days sewers were largely sewers of deposit, and were cleansed at intervals by manual labour. It was afterwards recognised that discharge into a river outfall was preferable to methods such as these. With the growth of population and the increasing provision of sewers, serious pollution of rivers occurred, and from 1848, the date of the first Public Health Act, to the present day, numerous Royal Commissions and Select Committees have reported on the best methods of preventing the pollution of rivers, and a number of Acts have been passed (see references at end of article). All the Commissions prior to the one now sitting, which was appointed in 1898, concurred in recommending land treatment in one form or another as the most satisfactory method of purifying sewage before discharge into a stream. This method was exemplified in the case of the Craigentinny meadows, which received the sewage of Edinburgh as early as the 18th century.

Application to land was effected either with a view to the growing of crops, by the method known as "broad irrigation," where the sewage was applied to the land simultaneously with the growth of vegetables, or by means of "intermittent downward filtration," a method introduced by Sir Edward Frankland in 1870, in the First Report of the Royal Commission of 1868. By this method the sewage is run on to an area of specially prepared land, and allowed to filter through, a further dose being applied after a period of rest. No attempt is necessarily made to grow crops, and the land must be kept open by ploughing. More sewage can be treated on a given area by this method than by broad irrigation; but there is no essential difference in principle between the two methods.

The amount which can be dealt with by either method is increased by preliminary removal of solid matters, either by simple settlement in tanks, or by the use of various chemicals as precipitants, of which lime, either alone or in combination with salts of iron or alumina, is chiefly used. The results from land treatment properly carried out on suitable land were so good, that until recently the Local Government Board refused to grant borrowing powers for sewage schemes, even where artificial filters were provided, unless provision was also made for final treatment on land. Owing to the increasing difficulty of obtaining such land in the neighbourhood of large centres of population, great attention has been given during the past twenty years to various methods of treatment by artificial filters of various descriptions.

In 1898 a Royal Commission was appointed to consider the whole question, and has issued numerous reports. It was able in its first interim report, issued in 1901, to give the following important finding:—

"We are satisfied that it is practicable to produce by artificial processes alone, either from sewage, or from certain mixtures of sewage and trade refuse, such, for example, as are met with at Leeds and Manchester, effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance."

Although the Commission is still sitting, and consequently no legislation has yet taken place, the Local Government Board have recently granted borrowing powers in several cases where artificial methods have been exclusively employed, without having recourse to land.

At the present time the administration of

the River Pollution Prevention Acts is in the hands of various Conservancy Boards, *e.g.*, the Thames and Lea Conservancy, the Mersey and Irwell Joint Committee, the Ribble Joint Committee, the West Riding Rivers Board, and Special Committees of County Councils. The degree of purity required before an effluent is allowed to enter a stream is somewhat differently defined by these various bodies. Thus the "limits of impurity" allowed by the Mersey and Irwell Joint Committee are 1 grain oxygen absorbed from permanganate by 1 gallon effluent, 0·1 grain "albuminoid ammonia" obtained on analysis, per 1 gallon effluent; while the Ribble Joint Committee and the Derbyshire County Council attach less importance to the "oxygen absorbed" figure, and more to the presence of nitrates and the consumption of "dissolved" oxygen by the effluent. The Thames and Lea Conservancy, on the other hand, having to safeguard the purity of the Thames, which supplies a portion of the drinking water of London, impose more exacting standards.

The present Royal Commission have recommended a central authority (see above) for the control of the purification of rivers and of water supply throughout the country. This central authority would act in conjunction with the present Rivers Boards and others likely to be appointed. They suggest that one of the functions of such an authority would be to formulate standards suitable for differing conditions. They recommend that the purity of an effluent should mainly be judged by the suspended matter present, and by the dissolved oxygen absorbed under defined conditions.

Owing to the fact that neither filtration by means of artificial filters nor through land can be relied upon to produce, under all circumstances, effluents free from pathogenic organisms, considerable attention has recently been given to the possibility of sterilising effluents, especially when they have to enter streams which are used as drinking water supplies. Although it has been found possible, within practicable limits of cost, chiefly by the use of chlorine in the form of hypochlorites, or oxides of chlorine (obtained by electrolysis), to sterilise effluents from isolated installations, such as hospitals, or even under some circumstances the dry weather flow of town sewage, the difficulty of the sterilisation of storm-water has so far proved an obstacle to the adoption of such methods on the large scale.

References.—Reports of Royal Commission on Sewage Disposal, 1901—8. London: Wyman & Sons, Ltd., 109, Fetter Lane, E.C.

An excellent *resumé* of the progress of legislation on River Pollution is given in the evidence of Mr. A. D. Adrian, C.B., Assistant Secretary to the Local Government Board. Royal Commission, Interim Report, Vol. II., 1902, pp. 1—14.

The general law relating to sewage disposal in England and Wales is to be found in the Public Health Act, 1875, supplemented by the Rivers Pollution Prevention Acts of 1876 and 1893. G. J. F.

Roads, Streets, and Pavements.—**General Consideration—Location, Gradients, and Drainage—Width of Roads—Retaining Walls—Embankments—Materials and Methods—Metalling—Repairs—Rolling—Paved Carriageways—General Method of Laying Wood Pavements—Asphalt Pavements—Tar Macadam—Brick Pavements—Paving Setts and Blocks.**

General.—The rapid growth of traffic during recent years calls for the construction of roadways upon the soundest and most permanent principles, embodying a solid and adequate foundation, good subsoil and surface drainage, together with a sufficient coating of durable road-metalling suited to the class of traffic to be accommodated.

Many of the highways of this country, formed in earlier years, have proved to be far too weak and inadequate to withstand the demands of modern conditions, mainly due to the absence of a sufficiently rigid foundation and to the employment of unsuitable materials for purposes of surface repairs.

The practice of using the cheapest stone obtainable in the locality cannot be defended

on the score of economy, inasmuch as the recent extended employment of tougher qualities of metalling has been amply justified from every point of view.

In some cases it may be found sufficient to provide a top coating of flints or granite upon the existing natural foundation, especially where the traffic is light and where the bottom consists of chalk or solid clay; but with the present day heavy traffic care must be exercised to insure that the foundation is of the best, and of a thoroughly firm nature. Such a substructure is essential to all good roads, and, although the first cost may be heavy, its provision will be found to be the cheaper course in the end.

Location, Gradients, and Drainage.—When new roads are to be laid out, the route is generally governed by existing roads, villages, and towns. In all cases careful surveys should be made of the district through which the road is to be constructed, and, where practicable, the route for the road should be one with the least amount of hills, provided the length is not unduly increased thereby. When making the reconnaissance the work will be simplified by the use of contour maps of the country traversed. On the route-map the engineer should note the available materials for embankments, where these appear necessary, the nature of the ground to be passed through, and any geological peculiarities on or near the route decided upon, with conditions in favour of or against the particular route to be adopted, and other alternative routes. When the route has finally been decided upon, stakes should be driven into the ground at frequent intervals along the centre line. Levels should then be taken longitudinally, with cross-sections at all necessary points. After these have been plotted the finished level can be decided upon, and the amount of excavation, filling, and banking, can then be ascertained.

Roads that are constructed of steep gradients are constantly requiring repairs, these being chiefly due to the erosion caused by rains, the abrasion by motor tyres in ascending, and the use of skids and brakes on vehicles descending hills, which cause disintegration of the surface. It is difficult to give limits to the permissible gradients, as so much depends on the local circumstances of the case, and the materials used. Several, however, have been given, and we may consider them at this point. Thomas Codrington has suggested 1 in 30 as the limit of gradient for macadamised roads. Sir John Macneil was of opinion that no road ought to exceed a gradient of 1 in 40. Sir Henry Parnell found by experiments conducted on the Holyhead road, north of Coventry, that a gradient of 1 in 35 should not be exceeded. Where roads are to be constructed through hilly districts, long, steep inclines should be divided up as far as possible into short lengths, with intervals of road of less inclination. This practice is especially recommended in the case of curved roads, these in addition being slightly embanked on the near side for the safety of descending traffic. Short lengths of smaller gradients not only tend to reduce the heavy strain upon horses drawing loads uphill, but are conducive to the safety of fast-driven vehicles and other traffic when descending, especially where the road has concealed turnings.

Perfectly flat roads are not desirable, as they cannot be well drained, and consequently remain damp for long periods, thus enhancing wear and tear, and gradual deterioration of the metalling. A moderate inclination of, say, 1 in 150, is about the flattest grade desirable, so as to enable the channel-water to be effectually drained away. A slight gradient also facilitates the draught of horses.

Even the hardest classes of metalling deteriorate more rapidly when constantly wet and damp, and for this reason it is advisable to insure, as far as possible, that the road should be open to the moderate action of the sun and wind. When traversing undulating country, the road should, if practicable, be constructed on the northern side of the valleys, and it is found that all obstructions, such as overhanging trees, high walls and fences and such like, are detrimental to the durability of the road.

It is not to be assumed, however, that it is permissible to go to the opposite extreme, and so subject a roadway to excessive exposure, as very strong drying winds have the effect of

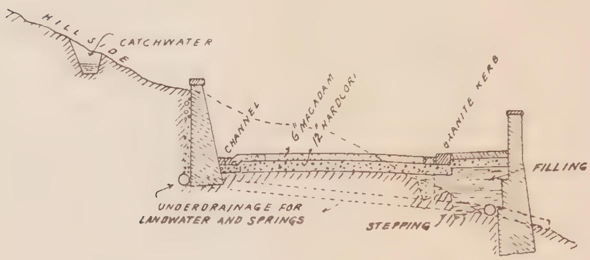


Fig. 1.

removing the "binding" material from the surface, and thus causing the roadway to disintegrate under traffic.

When passing through hilly country, in laying out a new line of roadway, it often becomes necessary, in order to find the ground over which the ruling gradients can be maintained to contour the hill-slopes, to cut into the side of the hill, and to embank on the down-slope, as shown in Fig. 1. The footpath should be arranged on the outer side, in order that the heavier vehicular traffic may be carried on the natural solid ground. Greater stability of that portion of the road which is embanked on the outer side is secured by "stepping" the added portion as shown, which tends to prevent slipping.

All springs or land water of every kind

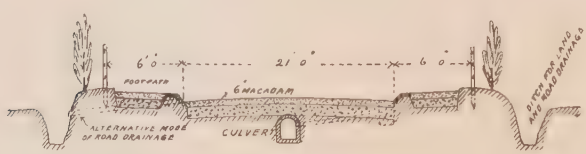


Fig. 2.

should be properly and permanently drained away to a point of discharge upon the solid ground, well below the outer retaining wall. Top-water above the upper wall should be intercepted by a suitable catchwater drain.

Roads of this description through hilly country often involve heavy engineering works, and are costly to construct, but very frequently the cost is materially minimised by the fact that good quality stone is obtainable from the ground traversed.

Other principal classes of roads are (1) ordinary country main roads; (2) country secondary roads; (3) roads of a suburban and residential class; and (4) pitched or paved roads of busy cities. These all require special types of construction, appropriate to each individual case, some examples of which are given in Figs. 2—4.

Country main roads require to be a minimum of about 21 ft. in width, or sufficient for three vehicles abreast, with two footpaths of 6 ft. width each.

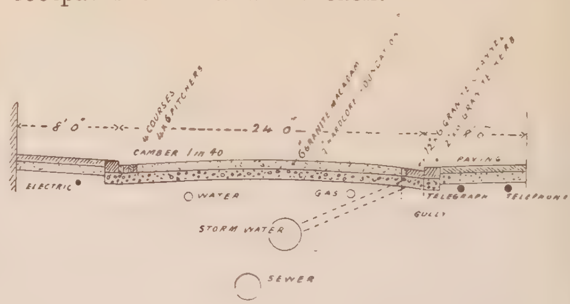


Fig. 3.

Suburban and residential roads are commonly 40 ft. wide overall, having two footpaths of 9 ft. width each, and a 22 ft. carriageway.

The trunk or main arteries through large towns may advantageously be 60 ft., and in special cases even 100 ft. in width, so as to accommodate ordinary vehicular, tramway, and pedestrian traffic.

The widening of important roadways through populated centres necessarily becomes a very costly undertaking, having regard to the fact that, usually, valuable properties on each side have to be purchased, including the trade interests of the various premises affected, in addition to which the cost of the structural works involved have also to be met.

Under some circumstances, particularly in

districts with widely varying levels, what is known as "hanging" and "double-hanging" roadways have to be formed. Typical roads of this class are shown in Figs. 5 and 6. An important point in all such cases is to secure the proper removal of the surface water, and

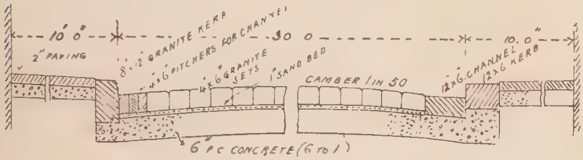
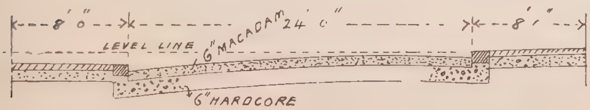


FIG. 4.

to see that the cross gradients are suited as near as possible to the requirements of the traffic. Sometimes it is necessary, in important cases, that a full-sized section of this cross contour should be built up, so that the effect of the finished road surface can be properly appreciated.

It is argued by some that a road with a *concave* centre is preferable to the common *convex* form, inasmuch as, it is suggested, the centre channel divides the traffic into up and down lines, one line of channelling and street gullies is needed, and the road-slop and water is drawn to the centre of the road, away from the footways, thus preventing the splashing

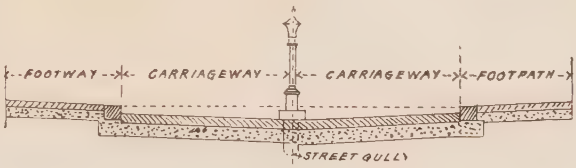


HANGING ROADWAY

FIG. 5.

of pedestrians in wet weather. Although this form of road may possess some good features from certain points of view, it must be remembered there are many disadvantages, and, on the whole, the balance is decidedly in favour of the ordinary form of road, except in certain special circumstances.

RETAINING WALLS.—These should be constructed of brick, stone, ordinary and reinforced concrete, and be of sufficient strength to successfully resist the thrust from behind. The thickness should be carefully calculated by means of reliable formulæ or graphically, the latter being the more expeditious method. Sir Benjamin Baker considered that the thickness, in average ground, should be one-third of the height of the walls, measured from the top of the footings, and in cases where the backing and foundations are both favourable a wall one-quarter of the height in thickness similarly measured, having a batter of 1 in. or 2 in. per foot on the face will be sufficient. Walls with a slightly curved face in vertical section, give better results and are more effective in supporting the thrust. Th esuccess of retaining walls depends largely on a well-distributed rigid foundation and upon proper drainage at the



DOUBLE HANGING OR CONVEX ROAD
UP AND DOWN TRAFFIC DIVIDED BY LAMP STANDARDS

FIG. 6.

back. Breast walls are not usually built to resist pressure from behind, but merely to protect the natural earth from the effects of the weather.

EMBANKMENTS.—There are many ways of constructing these, among them being the tip-wagon system. This is an expeditious method of carrying out the work, but is somewhat unreliable. The best method appears to be that in which the work is built up in successive layers or courses, each layer being concave in form and thoroughly consolidated as the work proceeds. Stability will thus be obtained for the whole structure, and especially is this the case when embankments are formed with slopes consisting of material resting at its natural angle of repose. The angle of repose of different materials in the table on page 368.

For embankments and cuttings exceeding 4 ft. in depth, Sir H. Parnell has recommended a slope of 3 ft. horizontal to 1 ft. perpendicular. For cuttings in chalk or marl a slope of one to

one will be sufficient; in solid, hard, and uniform sandstone slopes of one-quarter to one will suffice. Where the sandstone stratum is in alternate layers with clay or marl, the stone becomes detached and will slip, and for that reason hard and fast rules are difficult to give.

NATURAL SLOPES OF EARTH (WITH HORIZONTAL LINE).

Earth.	Angle of Repose.	Coefficient of Friction.	Customary Designation of Natural Slope.
Dry sand, clay, and mixed earth	From 30° to 21°	0·75 0·38	1·33 to 1 2·63 to 1
Damp clay ..	45°	1·00	1 to 1
Wet clay	From 17° to 14°	0·31 0·25	3·23 to 1 4·0 to 1
Shingle and gravel	From 48° to 35°	1·11 0·70	0·9 to 1 1·43 to 1
Peat	From 45° to 14°	1·00 0·25	1 to 1 4 to 1

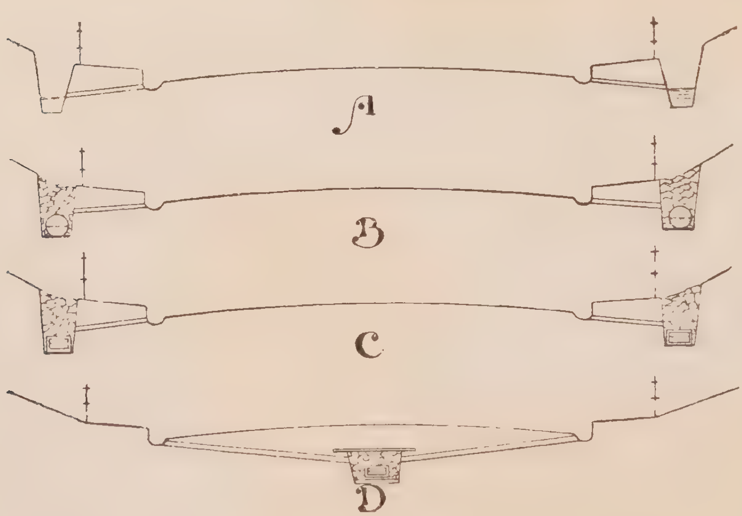


FIG. 7.—Drainage.

Slopes should be finished with a suitable material for grass growing, or, in cases where there is an excessive amount of water, with ballast.

DRAINAGE.—Care must be exercised in the formation of embankments, cuttings, and roads generally, to insure an efficient system of subsoil and surface drainage, as the stability of these works depends largely on their foundations being kept as dry as possible. The subsoil water from rising ground should be intercepted and carried away in the manner shown in Fig. 7A. This intercepted water can either be carried along the catch-water drain to the low-lying ground, or in a pipe drain down the slope, discharging at frequent intervals into the side channel of the road or into a covered drain. Land water drains can be either open roadside trenches constructed beyond the fences, or covered soaking drains, as shown in Fig. 7B. The latter are to be recommended, and may be formed of land pipes laid in the ditch and covered with large stones up to the level of the surface in the following manner:—The bottom of the trench is covered with hard material upon which is laid the open-jointed pipes. These are covered with large stones about 6 in. in diameter at the bottom and gradually reduced in size toward the top. The box-drain *C* and *D* (Fig. 7) is usually adopted in districts where stone is plentiful, the stone "bolt" taking the place of the drain pipes. Cross drains should be laid at distances varying from 25 ft. to 50 ft., according to the nature of the subsoil, and be connected to the covered drains in the sides, ditches, or trenches. In ordinary town macadam roads subsoil drains are rarely necessary, but when occasion arises they should be laid down the centre of the road parallel to its direction and connected to the surface water sewer. Water is carried off the surface of the road by forming its cross section to a slight camber. This will vary according to the material used, the following being found serviceable ratios:—

Macadam roads 1 in 30 to 1 in 40.
Wood paving . 1 in 45.
Asphalte. . . 1 in 55.

The water thus removed is conducted to channels formed at the sides of the roads and

is caught in catch-pits or gullies provided at frequent intervals varying from 80 ft. to 120 ft. according to the gradient. These pits and gullies are connected to the surface water sewer or covered ditch drain as the case may be. In order to provide a sill between the footpath and water channel a kerb is laid longitudinally along the road at a height of from 3 in. to 7 in. from the channel and the footpath is finished level with its upper surface. The materials used for such kerbing are either granite, stone, or iron. Granite and iron are the best materials for roads with heavy traffic, and for roads with light traffic sandstones, Kentish ragstone, cement concrete, or petrified fireclay block will be found suitable. The sizes used are usually as follows:—12 in. by 8 in. laid flat, slightly tilted towards the road; 6 in. by 12 in. laid on edge; 4 in. by 9 in. laid on edge. The lengths should not be less than 3 ft. The top surface and front face of stone kerbs should be hammer dressed, the back being dressed to a depth of 3 in. from the top. All ends should be dressed at least 6 in. from the top, to give close joints, and overflows should be cut in the kerb over each gully or catch-pit. The bed should be formed of 6 in. of cement concrete extending beyond the back face to a distance of 2 in. Channels may be constructed of granite in the form of lengths of kerb or setts of varying sizes, the beds being of concrete similar to that for the kerb, and extending beyond the face to a distance of 3 in.

Materials and Methods Employed in Broken Stone Roads.—Before treating of the covering or road surface the formation of the foundation must be dealt with. After the line of road has been excavated and shaped to the desired contour, material of various kinds is laid upon the surface to form the hardcore foundation. This consists either of (1) boulders or large stones laid "hand pitched," the stones being about 9 in. in depth, and, as a covering and also to fill in the interstices, a layer of smaller stones about 3 in. in diameter is then spread, and the whole well rolled solid; or (2) hardcore consisting of broken bricks, stone, clinker, or other similar material spread in layers, each layer being well rolled, the total depth of material varying from 9 in. to 15 in. according to the traffic the road will have to withstand.

Upon the foundation is spread the top surface coating, formed with such materials as the engineer has proved by experience to be the best. When deciding this, many points must be kept in view as to the requirements of a good carriageway, and among them are the following:—

1. The cost of construction and maintenance must be economical.

2. The material used must be durable and as noiseless as possible.

3. It must be firm and hard, and safe for horses, giving them a good foothold.

4. It must be sanitary, and as free from mud and dust as possible.

5. It must be impervious to moisture and impurities of every kind, and be easily cleansed.

6. It must be easily taken up and laid down again when required, after being broken up for gas, water, electric light, drains, and other trenches.

7. When used for a tramway the material laid down alongside the rails must be capable of withstanding the wear caused by the wheel flanges.

Major Isaacs, in a paper read before the Royal Society of Arts on the merits and demerits of road-making materials, compiled the following table from experiments bearing upon the above points, showing, in order of merit, the results of the different materials used.

	First.	Second.	Third.
Public hygiene ..	Asphalte	Granite	Wood
Noiselessness ..	Wood	Asphalte	Granite
Safety for horses under existing conditions	Wood	Asphalte	Granite
Cleansing ..	Asphalte	Granite	Wood
Durability ..	Granite	Asphalte	Wood
Economy	Granite	Wood	Asphalte
Facility of repairs	Asphalte	Wood	Granite
Facility for tramways ..	Granite	Wood	Asphalte

Broken stone roads continue to be in good

favour, and when the materials used have been carefully selected and properly laid, they can be adopted with economy on country and other roads subjected to medium and light traffic. They are, however, open to objections from a sanitary point of view, and constitute one of the chief difficulties in the dust problem. These objections have been dealt with in the article on "Dust Prevention."

Materials.—The materials used in forming macadam roads should be tough and of uniform hardness and durability. Brittle stones do not wear well and rapidly grind away into dust. Atmospheric influences affect many descriptions of stone, and care must be taken to choose one that will satisfy all the above conditions. To ascertain the wearing and other qualities of stone, trials should be made by laying lengths of different classes of stone in streets subjected to the same amount of traffic. The results can then be compared, and will include not only the result of the effect of the traffic on the stones, but also the effect of the weather and atmospheric influences and the binding properties of each. It has been found that moderately hard and tough stones are better than excessively hard stones for binding purposes. The engineers of the French Ponts et Chaussées have endeavoured to arrive at a comparative numerical value of the qualities of materials used on the national roads, and the coefficients of quality for the various materials are given as follows :—

	Coefficient for Wear.	Coefficient for Working.
Basalt	12·5 to 24·2	12·1 to 16·00
Porphyry	14·1 to 22·9	8·5 to 16·3
Gneiss	10·3 to 19	13·4 to 14·8
Granite	7·3 to 18	7·7 to 15·8
Syenite	11·6 to 12·7	12·4 to 13·00
Slag	14·5 to 15·3	7·2 to 11·1
Quartzite	13·8 to 30	12·2 to 21·6
Quartz Ore Sandstone	14·3 to 26·2	9·9 to 16·6
Quartz	12·9 to 17·8	12·3 to 13·2
Silex	9·8 to 21·3	14·2 to 17·6
Chalk Flint	3·5 to 16·8	17·8 to 25·5
Limestone	6·6 to 15·7	6·5 to 13·5

The coefficient 20 is equal to excellent, 10 to sufficiently good, and 5 to bad. Space will not admit of a full geological description of the formations from which these various rocks are obtained, but the reader is referred to geological books and survey maps from which the information can be obtained. The majority of road stones contain from 45 to 70 % of silica, and have a specific gravity varying from 2·50 to 29·5. A few of the best stones in use will now be briefly referred to.

Basalt.—This stone when obtained from the best quarries appears to withstand the wear of traffic better than many other classes. The Clee Hill basalt quarries in Shropshire produce one of the best road stones on the market. Owing to the great distance of the quarry from the coast and high rates for freightage, the price is prohibitive in some parts of the country, but where possible the stone may be used with great success, and though the first cost is sometimes heavy, a corresponding sum is saved in repairs and maintenance. This stone is hard and tough, and its peculiar construction makes it a good material for macadam, and it is comparatively free from dust.

Guernsey Granite.—This is a durable material but has a tendency to wear unevenly. It should not be used in hilly districts as it becomes rather slippery, but by carefully selecting the best blue stone success may be obtained.

St. Keverne.—This stone is exported from West Cornwall, and consists of a basaltic trap rock. It wears uniformly, and ranks as a good road stone.

Other Quarries.—There are many other quarries, too numerous to mention, from which excellent stone may be obtained, notably those in Leicestershire and Derbyshire.

Before adopting a new class of stone of which no local experience is available proper tests should be carried out, as the value of a road stone lies in its power to withstand the peculiar conditions and traffic of the district.

Haulage of stone on to the roads is an expensive item, and in many circumstances motor haulage will be found much cheaper and quicker than haulage by team labour.

Metalling. — The depth of metalling

required varies according to local circumstances and the character of traffic. Opinions differ as to the size of the stones to be used, but those ranging from $1\frac{1}{2}$ in. to $2\frac{1}{2}$ in. in diameter are usually employed. Some engineers prefer to use small stones and allow them to bind themselves together on being rolled; others prefer to use larger sized stones and use the "siftings" therefrom for "binding." A sandy material such as hoggin is also sometimes used. Stone, when properly riddled through a stone-breaker, contains 45 °/₀ of space previous to rolling, and after rolling interstices to the extent of 20 °/₀ still remain, so that the use of a binder is necessary.

Some engineers use road mud and worn surface material as a binding for road metalling, but the practice is a bad one and causes a heavy, greasy, and dangerous mud to be formed on the surface in wet weather, and a vast amount of dust in dry weather, thus increasing the cost of scavenging, watering, and maintenance. Siftings or hoggin make good binding materials, always look clean, and produce a minimum of dust and mud. It is false economy to use a cheap and soft "binding," as it increases the cost of scavenging, causes the road to disintegrate more rapidly, and adds to the dust nuisance.

The macadam should be laid to a total depth of 6 in. before rolling, the finished thickness being about 4 in. The stones should be evenly spread in two layers and rolled and watered to the required thickness. The first rolling should be on the dry metal, and after it has partly consolidated it may be watered. In some districts engineers use a top covering of granite and gravel or granite and flints, the layer of gravel or flints being 4 in. in thickness and the layer of granite being 2 in. in thickness, both layers being watered and rolled to a total depth of 6 in. It has given good results and can be constructed at less cost than a road surface having a consolidated thickness of 4 in. of granite. The cost of macadam roads varies according to local conditions, but the following table of the cost in a London district may prove useful.

	2 in. of Guernsey Granite on 4 in. of Local Flints.	2 in. of Enderby Granite on 4 in. of Local Flints.
	s. *d.*	*s.* *d.*
Cost per cubic yard ..	16 0	13 6
Unloading	0 $4\frac{1}{2}$	0 $4\frac{1}{2}$
Loading	0 3	0 3
Haulage	0 10	0 10
Cost per cubic yard on road, say, ...	17 6	15 0
Cost per super. yard 3 in. thick on road	1 $5\frac{1}{2}$	1 3
Flints, local, 6*s.* cubic yard on road, 4 in. (6 in. before rolling), cost per super. yard	1 0	1 0
Cost of material 6 in. in thickness when rolled	2 $5\frac{1}{2}$	2 3
Spreading and rolling ..	0 3	0 3
Total cost per super. yard	2 $8\frac{1}{2}$	2 6

To this cost must be added that of the foundation and excavation, and the total works out at from 4*s.* 6*d.* to 6*s.* per superficial yard.

Repairs.—It is usually desirable to loosen the top surface of the old materials on roads previous to applying the new stones. The bed is then formed to the desired contour, and some of the old material after screening may be used in conjunction with the new for the repairs. Hand picking is largely resorted to, the road surface being broken across at frequent intervals with grading picks varying from 6 lbs. to 9 lbs. in weight. The repairs on inclines should be commenced at the foot and worked up the hill. Hand picking costs about $1\frac{1}{2}$*d.* per superficial yard. The whole of the surface should be equally broken and reformed. If the surface has worn hollow, total picking up of the road may be undesirable, and after a good watering or in wet weather the new material may be put straight on to the old surface to the required thickness and contour, and to bind it well into the old road it will only be necessary to pick up the road

along the edge of the water channel for a width of about 12 or 18 in. Many scarifiers have of recent years been introduced by which the road surface may be broken by machinery. These machines pick up the whole or any portion of a macadamised road surface where required with rapidity and economy. Messrs. Aveling & Porter's "Morrison" scarifier is often attached to a steam road roller, and can be put in and out of operation at will, and worked either backwards or forwards. Rutty's scarifier is another good appliance. This consists of a heavy cast-iron frame, into which are fixed six movable steel tines, or teeth, three at each end, one set being used at a time, according to the direction in which the engine is moving. The machine is drawn along by the steam roller, to which it is connected by a chain, which relieves the engine of the vibration inseparable to the work of scarifying. Other scarifiers in use are Jackson's scarifier, Voysey's & Hosack's scarifier, Wallis Road-Pecking Machine, Fowler's "Evershed" scarifier, and W. Thackeray & Son's machine. There is a saving of from 35°/₀ to 50°/₀ by the use of a scarifier as compared with the cost of hand picking. In an experiment carried out with a Rutty's scarifier it was ascertained that, after paying all expenses and providing for wear and tear of machinery, the total cost averaged at the end of one week's work rather under $\frac{1}{2}d.$ per yard superficial of work done.

Rolling.—This is a necessary part of the work in road making and repair, as it economises both time and material. In consolidating road metalling it is a great mistake to use too much water—only a small quantity is required by an experienced driver. The road should not be rolled in short lengths, as the engine will have to be constantly reversed, which entails excessive wear. Statistics have been published as to the superficial area and relative cost of rolling work done in a specified time, but the results vary widely.

A record has been made of each day's work in Penzance in order to arrive at the average cost of the rolling done. The quantity of material laid and the superficial area rolled were booked at the end of each day, with the result that a good day's work in thoroughly consolidating town roads, subject to the interference of traffic, &c., was found to be 450 to 500 superficial yards of material consolidated, the cost averaging from $\frac{3}{4}d.$ to $1d.$ per yard superficial, or $5\frac{1}{4}d.$ to $7d.$ per ton of road stone, the calculation including wages, coal, oil, waste, brooms, team work, watering, depreciation of steam roller and plant. But the average cost for the whole period in patching and general work, including time lost, was nearly double.

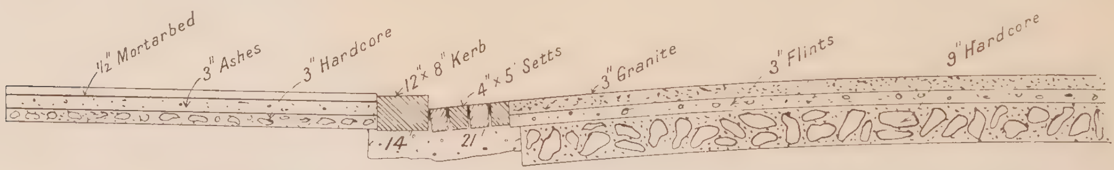


Fig. 8.—Cross Section of a Macadam Roadway coated with 3 in. of Flints and 3 in. of Granite.

Paved Carriageways.—Paved carriageways are of two descriptions, viz., those which are laid with transverse joints from kerb to kerb, such as wood blocks, granite setts, bricks, &c., and those which are free from joints, such as asphalte, tar, macadam, &c. The use of wood for street paving purposes has become general in this and other countries of recent years. Soft wood pavements, which are so called to distinguish them from the harder and denser woods of Western Australia, have been favoured by some authorities on account of their combined qualities of noiselessness and comparatively low initial cost of construction. The drawback to the employment of soft wood, however, is its short life as compared with the hard woods. Since the advent of wood pavements many endeavours have been made to

produce a material by chemical or other means which will increase the life of various soft woods and render them more durable and sanitary for street paving. The methods adopted have to a great extent met with success, so much so that the softer description of woods so prepared have become more extensively used. Some of the processes by which the wood is treated may be briefly explained. "Creosoting" consists of subjecting the wood to immersion in the oil known as creosote, which soaks into the pores of the wood, serving both to keep out the atmospheric influences and to check decomposition. Creosote is sometimes forced into the wood under pressure so as to impregnate the timber to as large a degree as possible. For this purpose the blocks are placed in an iron boiler containing boiling creosote oil; the boiler is then closed and an internal pressure of 130 lbs. to the square inch is applied to force the oil into the wood, each cubic foot of wood absorbing from 8 lbs. to 10 lbs. of oil. It appears that when blocks are so treated under pressure the wood is often damaged and its life reduced—the fibre and pores of the wood being injured thereby; at any rate the resulting wear will not warrant the extra cost incurred. The great point to be observed in all soft wood paving blocks is to insure them being well seasoned previous to their being creosoted. They must be free from sap, or the creosoting will be the very means of defeating the object for which it is used. Instead of preventing decay the creosoting will cause rapid fermentation in the heart of the wood, and will within a comparatively short period produce rapid deterioration and rot. It is useless to attempt to season the blocks after the process is applied. This precaution should be taken in every case where any preservatives are resorted to. Burnett's process consists of a solution of chloride of zinc and water in the proportion of 1 of chloride of zinc to 45 parts water. This solution is forced into the wood under a pressure of 130 lbs. to the square inch, or, as in the case of creosoting, it can be applied by immersion for a lengthy time. Chloride of zinc renders the wood incombustible. Gardener's process is employed with the intention of dissolving the sap and driving out the moisture from wood by means of chemicals, leaving the fibre only to remain. On completion of this process other chemicals are employed to render the wood more durable and incombustible. Ryan's process is a solution of corrosive sublimate, or bichloride of mercury and water. The timber is immersed for a period of about 30 hours for each inch in thickness for soft wood paving blocks. The solution is made in the proportion of 1 of bichloride of mercury to 130 to 150 gallons of water. This process increases the density of the wood and retards dry rot in seasoned wood. In 1839 the first wood pavement was laid in London on the Stead's system, in front of the Old Bailey. Half a century later, in 1889, the first hard wood pavement was laid in Westminster Bridge Road. Some of the best known systems of wood pavements are:—

Asphaltic Wood Paving.—This consists of a concrete foundation covered with a layer of mastic asphalte $\frac{1}{2}$ in. in thickness, on which creosoted wood pavement blocks are placed, with about $\frac{1}{2}$ in. spaces between each row. These spaces or joints are then partly run in with melted asphalte, which readily unites with the similar material previously laid over the foundation. The remaining portion of the joints is then filled in with cement grout or lias lime.

Henson's Wood Pavement.—In this system the paving blocks are laid on a concrete foundation covered with well-tarred roofing felt, a strip of which is also placed between every other course of blocks while being laid. The courses are driven closely together with heavy sledge hammers, a plank being previously placed against the blocks. The work is grouted in with pitch. This road is supposed to be rendered as noiseless as possible by the elasticity of the tarred felt.

Harrison's Wood Pavement differs from the asphalte wood paving in one respect only. Instead of the under laying of mastic asphalte,

the blocks are raised about ½ in. from the foundation on strips of wood, and hot asphalte is then run through the joints until the space between the concrete foundation and the wood pavement, and also the joints, are all filled in one process.

Improved Wood Pavement.—The Improved Wood Pavement Company originally laid wood blocks on two thicknesses of 1 in. tarred boards. laid so as to cross over each other at right angles, and which formed the only foundation over the ordinary road bed. The improved road system consists of the following: — Upon a foundation constructed of 6 in. of Portland cement concrete, faced over with ¾ in. thickness of cement mortar to the camber required for the pavement when finished, a covering of creosoted red Northern fir blocks, each measuring 8¾ in. long, 3⅛ in. wide, and 6 in. deep, is laid. The blocks are set with close longitudinal joints and ⅜ in. transverse joints, the spaces between the blocks being regulated by the temporary insertion of strips of wood, which are afterwards removed. Hot pitch is then run into the open spaces, which fills any irregularities existing between the foundation and the wood covering and also partially fills the joints. The joints are finished with a grouting of neat cement, broomed over the surface until it is rendered as impermeable as possible. A coating of fine gravel is, on completion, thrown over the surface, to be forced into the face of the wood by the weight of the traffic. The gravel which is spread over the face of the work wears into the wood, forming a hard crust and indurating the wearing surface of the pavement.

Duffy's Dowelled Pavement.—This pavement is laid on a foundation of concrete or other material of the thickness required. The blocks are bound together by dowels inserted into recesses on each side of the block. This system provides for the weight of the traffic to be spread over a wide area, and, therefore, there is less need of heavy foundation works. The thickness of the blocks can also be reduced. It is particularly well adapted to swing and other opening bridges and for street paving generally.

There are many other systems of wood paving invented, with interlocking joints, elastic foundations, grooves at the sides and grooves in the surface, but in practice it is found that complications of construction militate against general success, besides adding to the cost of the work.

General Construction of Wood Pavements.—Wood blocks are usually made 9 in. long, 3 in. wide, and 4½ in. deep, but some are used 5 in. to 6 in. deep. The only real advantage to be derived from the use of the deeper blocks is that when one side is worn uneven the blocks can be reversed and used again. When the blocks are reversed with the worn side turned against the concrete foundation, it is necessary to adopt some system for levelling up the surface, such as a bed of mortar or sand about ¾ in. deep. In the eastern colonies a large quantity of wood paving has been carried out with blocks of 7 in. and 8 in. long, and blocks of 6 in. by 3 in. are much used in New Zealand. The shorter the block the greater is the saving in cost, as the use of the 9 in. size necessitates much waste of timber in cutting. The shorter sizes have less tendency to warp and become loose through "rocking" after laying, and they are, as a matter of fact, more easily seasoned, and there is no reason why these reduced lengths should not be employed in this country. The chief timber employed for soft wood pavement is yellow deal and Baltic redwood, although oak, larch, and fir have been used from time to time.

General Method Employed in Laying Wood-block Pavements.— In laying wood pavements of all descriptions the system known as close blocking is to be recommended, excepting where the gradient is steep. For gradients up to 1 in 45 close blocking is considered to be the best system, but with attention to the method of laying there is no reason for prohibiting the use of wood blocks on gradients up to 1 in 25, or even 1 in 15 with due attention to gravelling in wet

weather. On gradients it is advisable to space the transverse joints of every other row of blocks about an inch apart—or in special cases it may be advantageous to space every row—so as to give a better foothold for horse traffic; and the camber of the paving on hills should be less than that usually employed on level roads, otherwise horses have a tendency to slip sideways, with extremely dangerous results. The general practice is to make the contour, or cross-section of the road, a segment of a circle, giving a fulness at the "shoulders" of the pavement, which carry the traffic on each side of the road. The degree of convexity must be considered in conjunction with the longitudinal section, as to whether this be flat or inclined. On the level the camber allowed to pavements should average 1 in 60, and on gradients this should be from 1 in 70 for moderate inclines, and 1 in 80 to 1 in 90 for hills up to 1 in 30 and steeper. The best results from wood pavements are obtained by laying the wood blocks with the fibre vertical. Since the introduction of wood for the paving of streets the blocks have been cut in various directions to the grain; for instance, in De Lisle's system the blocks were cut diagonally to the grain, and also in the Trenaunay's system used in France and introduced into England under the name of the "Lingo Mineral Pavement." By placing the grain vertical, the life of the wood is much increased over oblique or horizontal cutting. The first question of importance in laying wood pavements is to provide a thoroughly reliable foundation which will remain intact after the wood covering is worn out. Concrete is the best material for this foundation, and this should be constructed from 6 to 9 in. deep, over a well-consolidated and properly formed road-bed. The face of the concrete should be finished to a smooth surface and formed to the convexity required for the wood paving. Screeds are made by the carpenter to fit over the road-bed. These are placed vertically across the road at distances of about 5 ft. apart. The spaces between these vertical screeds are then filled with concrete of good quality, the top portion being finer concrete than the bulk. The surface is rendered smooth and to an equal curvature throughout by drawing a suitable straight-edge across the screeds, as shown in Fig. 10. The bed for the blocks may consist of sand or any other mobile material on the concrete foundation, or a layer of asphalte, tar, or tarred roofing felt. The

FIG. 9.—Concrete Paving.

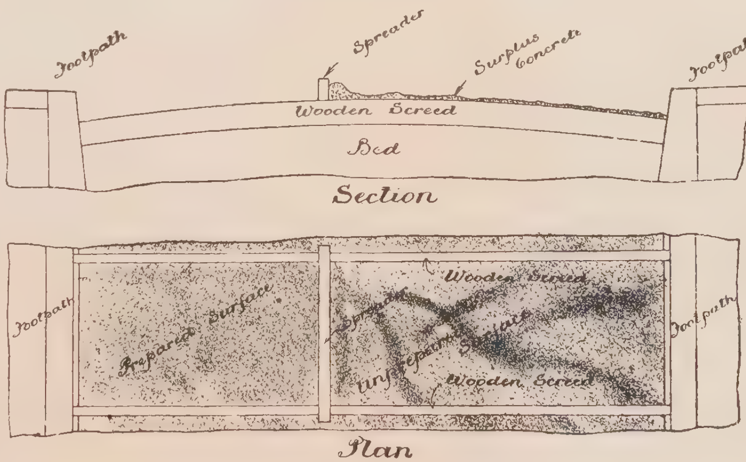


FIG. 10.—Concrete Paving.

wood blocks should be dipped three-quarters of their depth into a boiling composition of coal-tar and pitch, which is delivered hot from the cauldron on to the work in shallow dipping-trays. The blocks are then set in their places, one against the other, in perfectly straight lines from kerb to kerb; and as soon as a few blocks are set in their places by hand a flat piece of wood is placed against their face, and with the assistance of a sledge hammer or wooden mallet the blocks are driven perfectly close together, both transversely and lengthwise. On completion of the day's work, and before any of the surface is

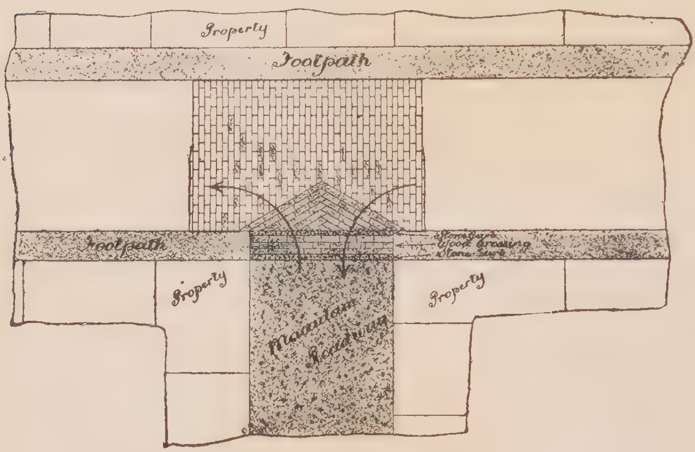


FIG. 11.

exposed to rain, the joints should be well grouted, and the surface also coated with boiling tar and pitch, and immediately covered with a $\frac{3}{4}$ in. layer of fine gravel and sand. In laying the wood blocks, every alternate course must be commenced with a half block in order to break the transverse joints. By laying the wood blocks diagonally across from kerb to kerb there should be less wear and tear on the joints, and the arris of the blocks should remain intact for a longer period. This plan provides a much more comfortable pavement to traffic, and with the present-day fast modes of locomotion its adoption is recommended for the consideration of engineers. When laying blocks diagonally across streets the first and last blocks in each row will be cut to the angle at which the rows are laid from the channel courses. At all junctions of roads the blocks should be laid diagonally, as shown in Fig. 11, otherwise it will be found that the wheels will cut the transverse unbroken joints and soon cause the road in these positions to suffer from undue wear. The channels are usually formed by laying three or four courses of blocks lengthways with the street, near the kerbs. Two of the longitudinal joints in these channel courses are usually made about an inch wide, with the one near the kerb filled with mortar of medium quality, and the outside joint filled with clay mixed with a small quantity of lime. These will allow for the expansion of the pavement, and when the outside joint, which is filled with the more tentative material, is entirely closed up the second comes into action. It is a mistake to make it too easy for the pavement to expand, for by leaving one wide joint of about $1\frac{1}{2}$ to 2 in. clearance on each side of the street merely filled with compressible clay the weight of the traffic will cause the pavement to creep imperceptibly from the crown of the road to the sides, and that which is sometimes thought to be expansion of the wood is nothing more than the opening of the longitudinal joints; but by giving the pavement a sufficient support to butt against on each side of the road, the expansion trouble will be minimised the pavement joints will be kept water-tight, and the wear of the blocks will be increased. Should the pavement show signs of expanding and a slight rise in the centre, it is an easy matter to uncaulk this joint and re-make it, when the road has taken its proper bearing. This, however, rarely occurs if the nearest expansion-joint is properly made. It is most important that every part of the work during the process of laying wood pavements should be perfectly dry. The foundation must be as dry as possible, the wood blocks perfectly dry,

and the tar composition must be distilled. The work is expected to remain on completion for a lengthy period, and whether this be 5 years or 20 years, it is a question depending very much upon the care taken on all points in its construction.

Although a well-creosoted soft wood pavement properly laid, and with strict attention to seasoning and quality of wood before treatment, will make a comparatively durable and sanitary pavement, many engineers state that the Australian hard woods surpass all others from every reasonable point of view, and although the first cost of the latter exceeds that of the soft woods, it will be found much the cheaper pavement in the long run. They find that hard wood loses less by shrinkage, and costs less in sanitation, scavenging, and wear (but this is a very debateable point); whilst soft woods cost less in construction, are less noisy under the traffic, and less slippery than hard woods. Hard wood will cost twice that of creosoted deal, and in some cases has been found to wear three times as long. It will be found in practice that if by once laying the hard wood pavement will have a life of 75% over and above that of soft wood, the additional cost of the former will be warranted. If, however, soft wood pavements are thoroughly gravelled before the traffic is turned on to them, and watched very closely and gravelled at periods of not less than one month, the life of these pavements will be found to be almost equal to that of hard wood pavements. There is one great advantage with soft wood pavements, viz., that when properly and skilfully maintained the surface is always even, while hard wood pavements have a great tendency to become bumpy. Comparing the advantages and disadvantages, it appears that soft woods are the better pavements for traffic of any description. A soft wood pavement with foundation complete will cost from 10*s.* to 14*s.* 6*d.* per square yard, and the usual price for hard wood paving including foundation is 15*s.* to 17*s.* 6*d.* per square yard; the cost of the concrete foundation and the laying being practically the same in each case, the difference being in the cost of the blocks. The hard woods of the Western Australian forest are very numerous, but the two principal timbers employed for street pavements are known as Jarrah and Karri; the former growing in greater quantities and being first from a commercial point of view. These woods get extremely hard with age, and are then almost indestructible. In appearance there is but little to distinguish the Jarrah from the Karri; they are both red in colour, hard, heavy, and tough, but the Karri does not dress so easily and smoothly as the Jarrah, and when burnt the former leaves a good deal of white ash, but the latter whilst burning looks black and leaves practically no ash. Karri makes a less slippery road than Jarrah. It is difficult to judge the better of the two woods for paving purposes, so long as they are both well seasoned before laying. Hard wood blocks require to be well seasoned, and Karri more so than Jarrah. The following results were obtained at Penzance by seasoning Jarrah and Karri blocks and experimenting with them to ascertain their qualities of absorption, shrinkage, and expansion, under varying conditions. The greatest penetration in Jarrah was one-sixteenth of an inch, and the least depth one thirty-second part of an inch, whilst Karri unseasoned absorbed four drachms of water more than Jarrah; but when both were seasoned Karri gave a conflicting result of two drachms less absorption per block than Jarrah; and in seasoning, the former, which was originally 9 in. long and 3 in. wide, had been reduced to $8\frac{3}{4}$ in. long and $2\frac{7}{8}$ in. wide. If, therefore, a permanent close joint is required it is most essential that all the wood blocks should be stored before laying, and the longer they are kept the better the pavement will wear. Well-seasoned hard wood does not expand or contract to any appreciable extent; but when laid soon after arrival the result varies. In hot dry weather hard woods shrink, the joints open and become filled with grit and dust, and as soon as the wet weather attacks them and they require room for expansion, they cannot occupy their

original positions because the spaces between them are filled with grit, &c.; so the whole covering moves towards the sides, under the weight of the traffic, and the expansion takes place at the expansion-joints provided near the channel on either side of the street, and without the expansion-joints the centre of the road would become "hog-backed." Australian hard wood is effective in resisting moisture and decay, and its non-porous character renders it a particularly sanitary material for pavements. A road constructed with it will dry in less time after rain than pavements made of soft wood or macadam.

Asphalte Pavements.—Asphalte has been used for the surface coating of carriageways with considerable success for the past 40 years in England, and has also been largely employed in France and the United States of America. Natural asphalte is a form of limestone or sandstone in union with mineral pitch or bitumen. Limestone asphaltic rock contains from 5 to 15 °/₀ of bitumen, and sandstone asphalte contains bitumen in varying quantities of 50 °/₀ and upwards. These materials are obtained from Val-de-Travers, Switzerland, Limmer near Hanover, Brunswick, Ragusa, Sicily, France, Germany, and Trinidad. The last-named locality produces the best bitumen for asphalte pavements, and many of the extensively used thoroughfares in London have been laid therewith. This material is very satisfactory under heavy traffic. The Val-de-Travers rock is brought from the mines into this country in its raw state, where it is prepared for use. It is ground to a fine powder, and after being heated is conveyed in a semi-plastic condition on to the works in covered carts. The material is then evenly spread, by means of rakes, over the surface of the road foundation, and compressed with heated rammers or pillows, and afterwards smoothed off with irons or rollers. This asphalte is usually finished to a thickness of 2 in., and is laid on a foundation of 6 in. to 8 in. of cement concrete. The asphalte cement, as used extensively for road pavements, is obtained by refining crude bitumen from the pitch lake of Trinidad, and for use on foot pavements suitable proportions of carbonate of lime and sand are added. In order that this material should not lack plasticity a small quantity of residuum oil of petroleum is added to the distilled bitumen.

Mastic Asphalte.—Mastic asphalte has practically ceased to be employed for pavements of recent years, preference being given to the dry process. When this was used the mixture of ground asphaltic rock and bitumen was heated in cauldrons on the site of the work, and when sufficiently melted dry clean sand and gravel were added, and boiled in the liquor for an hour or two. The material was then run out over the surface of the foundation, and smoothed down with hot irons and rollers.

Barnett's Asphalte resembles the mastic asphalte, but contains a small proportion of iron ore, which was supposed to increase the life of the pavement.

Camber.—Asphalte pavements require very little camber in cross-section. With so smooth a surface, the water will have no difficulty in draining off if the convexity of the road is made with an average rise of 1 in 85, or less in the case of limestone asphalte pavements, these being more slippery than Trinidad. Trinidad asphalte pavements can be laid on gradients up to 1 in 30 with proper attention to cleaning, and limestone rock asphalte should not be laid on gradients over 1 in 50.

Roadamant.—A new material, manufactured by the "Roadamant Asphalte Company, Ltd.," has been introduced, and from the trials made with this asphalte composition on the Victoria Embankment, London, and other places, it would appear that many of the complications connected with the laying of asphalte pavements, which prohibit their more general adoption in some provincial towns, will be overcome. The asphaltic material is incorporated with the stones of the respective districts and can be easily laid by local road-makers. "Roadamant" is found to give a very high record of resistance to crushing, compares very favourably with

other forms of asphalte, and its use is calculated to considerably reduce the ultimate cost of road repairs. The manufacturers claim that it is impervious, dustless, silent, expeditiously laid, comparatively inexpensive, and possesses the feature of being non-slippery to horses and other traffic. When laid on a foundation of 6 in. of concrete it costs from 10*s.* to 11*s.* per yard superficial, including foundation, and its life is claimed to be from 10 to 15 years, according to the amount of traffic to which it is subjected. The manufacturers also claim that the average cost per superficial yard per annum is less than any other description of pavement, being only 10·132*d.* per square yard per annum, including first cost, spread over a period of 15 years.

Sanitary Block Pavement.—This asphaltic pavement has been extensively used in the United States of America, and is now laid by the Hastings Pavement Company in this country. It consists of asphaltic blocks made of a mixture of refined lake pitch and crushed trap-rock, incorporated at a temperature of 200° F. Whilst at this temperature the material is manufactured into blocks under a pressure of 120 tons. The blocks measure 4 in. by 12 in. by 3 in., and 4 in. by 12 in. by 4 in., and they weigh 13½ lbs. and 18 lbs. respectively. Asphaltic pavements should be laid on a concrete foundation similarly constructed to that used for wood-paved carriageways, but with less camber. The surface of the concrete must be quite dry at the time of laying the asphalte, otherwise the pavement when completed will be found full of little holes just beneath the surface, and these will cause the road to wear badly.

Tar Macadam.—There is perhaps no pavement of more varying qualities than tar macadam. Simple as its construction may appear to the inexperienced, its success depends upon strict attention to the proper treatment of the materials used. The preparation and incorporation of the cementing composition, the conditions upon which the work is executed, and the description of traffic to which it is to be subjected must all enter into the computation, as neglect of any one point will militate against success. If tar macadam is efficiently made, it forms one of the most valuable of materials at the disposal of the road engineer, and when properly laid will be found to be durable, and is capable of withstanding a considerable amount of traffic. The usual method adopted in preparing tar macadam for roads is to heat clean macadam stones over purposely made furnaces, and then to mix them with a proportion of boiling tar, pitch, and creosote oil, the relative proportions being one barrel of coal tar, 1 cwt. of pitch, and 4 gallons of creosote oil. The mixture of stones and tar is ready for use soon after cooling, and is put on the dry road formation in two layers. The bottom layer is about 4 in. in thickness and composed of large-sized stones about 2½ in. in diameter, and the top layer or surface coating is about 2 in. in thickness, composed of stones about 1 in. in diameter. Each coat is well rolled, and the total thickness varies from 3 in. to 6 in. The surface is well sanded previous to the traffic being admitted over it. Tar macadam can be used for repairs to roads, channelling, footpaths, and a variety of other purposes.

The Val-de-Travers Asphalte Macadam has met with success where it has been laid, and its price places it within the reach of most highway authorities. In this process the ordinary asphalte rock is broken up into angular pieces, each capable of passing in any direction through a 2 in. ring; it is then carefully spread and levelled over the surface of the road to an even thickness of about 4½ in. and compressed by rolling. A steam roller of 10 tons weight will compress the thickness to about 3½ in. If the material is to be used on a road already formed and having a good foundation, nothing more is required than the removal of the top crust to a sufficient depth to take the new covering, the road-bed being well rolled and ready to receive the asphalte. In the case of a new road, or one not having a sufficiently good foundation, the ground must be taken out and

removed to the necessary depth, and a layer of broken stone, clinkers, or brick rubbish, about 6 in. thick and well consolidated by rolling and formed to the proper camber, will be all that is required to form the foundation, and upon this is laid the surface coat of asphalte. Val-de-Travers asphalte macadam forms a perfectly smooth, even, noiseless, and sanitary pavement, affords a good foothold for horses, and wears well under all classes of traffic.

"Plascom" Patent Composition Grout.—This material, which is manufactured by the Plasco-Bitumite Company, Ltd., has proved itself to be an inexpensive preparation for adding to the life of macadamised roads, and renders them more sanitary. The mode of construction of carriageways and other works recommended by this company is as follows:—In the case of remacadamising an existing road the ordinary method should be adhered to, viz.:—First scarify the surface, regulate and steam roll the foundation exposed until it is thoroughly consolidated. Upon this lay the necessary coating of granite, furnace slag, limestone, or other material proposed to be used, and if not more than 4 in. in thickness it may be treated in one layer. Bring all the work to as near the finished levels as possible, with proper falls and camber, and after again steam rolling prepare the surface for grouting. Care should be taken to see that "Plascom" is well boiled to a good temperature (say 300° F.) before using, as it will then become quite fluid and run freely. Next proceed to pour the compo over the surface material above referred to and fill up the whole of the interstices until thoroughly grouted, cover the surface with a thin layer of ¼ in. chippings while the "Plascom" is hot, and roll with the front wheels of roller almost immediately to keep work in shape, and, after cooling down (but before the compo sets, which it does very quickly), well and thoroughly roll to finished surface. The manufacturers of this material claim that the ordinary traffic may be turned upon each section immediately it is completed and no damage is caused to the new surface. The composition can be easily liquefied in an ordinary tar boiler. If the boiler is first only filled to one-fourth of its capacity, and after the composition becomes liquefied fed until the necessary quantity is put in, the grouting material will be ready for use more quickly. In order to thoroughly incorporate the material and derive the full benefit from the more valuable properties of "Plascom," the material should be thoroughly stirred, and especially is this the case when drawing off the liquid through the tap. The same procedure may be followed so far as it applies in the treatment of new roads, but it is very essential that the foundation should be constructed with good hard material, not less than 6 in. thick, and the interstices filled up with small-sized stone, and well rolled before the surface layer of broken stone is put on. For grouting sett paving the packing should be cubical in shape, with a minimum size of ⅜ in., dry and free from dust, and a thorough grouting from top to bottom is then assured. Clean gravel of the size mentioned gives excellent results. One ton of "Plascom" will grout 50 yards super. of paving. "Plascom," if well boiled when used for grouting wood paving, will run as freely as pitch and creosote oil, and is much more satisfactory owing to its plastic and adhesive properties. It sets more quickly than pitch. This is particularly advantageous, especially in case of repairs to streets where the vehicular traffic may be congested, as it acts as a safeguard against foreign matter being driven into the body of the grout, prevents water percolating through the bad joints into the under bed, and preserves the paving. One ton of "Plascom" will grout 70 yards super.

"Tarmac."—This material is manufactured from ironstone slag and is thoroughly impregnated with tar oils. It is supplied from the works ready for immediate use. The material is easily laid and consolidated with the minimum duration of rolling, and when finished the road is impervious and durable, and possesses the advantages of a macadamised road without its drawbacks. It forms

an economical road covering, and cleansing charges are reduced by its use. The following details for the application of "Tarmac" are recommended by the company :—For roadway purposes, before applying "Tarmac," the road surface should be smooth, and all loose stones removed. It is not necessary to have a special concrete foundation for "Tarmac." Holes and inequalities in the surface should be cut out, first tarred, and then patched with fine "Tarmac," these patches to be well rammed with a road rammer until the surface is level. "Tarmac" being quite impervious to water, a camber of 1 in 50 is sufficient to keep the road dry. The first coating should be carefully spread, rolled to a depth of about $1\frac{1}{2}$ in. with a roller of medium weight, and any shaping of the road required must be done in this application. This layer should have, if possible, two days' drying before applying the second layer. The finished face is best made with a close layer of finer material, $1\frac{1}{2}$ in. gauge evenly spread, and rolled to a thickness of $1\frac{1}{2}$ in., the total final thickness being about 4 in. When the whole is sufficiently rolled, a fine covering of slag dust should be carefully spread over the surface, and later the surplus should be swept off. It is not advisable to use too heavy a roller, one of about six or seven tons is sufficient. Ironstone slag not treated (of size to pass through a $3\frac{1}{2}$ in. ring) is very suitable for the foundations of new roads. In unloading trucks the doors should be opened and the material shovelled from the bottom in order to insure its being properly mixed.

Brick Pavements.—Bricks have been used for paving purposes in the United States of America and other countries for several years, but they have not been extensively adopted for pavements in England. Trials have been made from time to time in various localities in this country with varying results, more failures having to be recorded than successes. Bricks are very apt to wear unevenly, to chip and become slippery. In the United States of America brick pavements are recommended as one of the best forms of paving materials. In selecting bricks for pavements care should be exercised to see that only those of the best quality are used. They should measure $8\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by 4 in., absorb not more than $2\frac{1}{2}\%$ of water, when immersed for 12 hours after being thoroughly dried, stand a cross-breaking stress of 2,500 lbs. if made from a good shale, should be free from lime, highly burnt and annealed, and of uniform colour, especially when used for footpaths. They should be hard, tough, and impervious, and have a resistance to crushing of at least 7,500 lbs. to the square inch. The edges of street paving bricks should be pressed and slightly rounded. Brick pavements should be laid on a foundation of concrete similar to that recommended for wood and asphalte pavements. The bricks are bedded close together on a thin layer of mortar, over the foundation, each row breaking joint as in the case of wood paving, and at the completion of every few yards of work the surface should be carefully rammed till the bricks are level. As soon as the surface is levelled and formed to the proper camber, the joints should be grouted with liquid cement.

Paving Setts, Cubes, or Blocks of Stone, when used for paving purposes, are durable and cleanly. Granite becomes slippery, is immensely hard and unyielding under the feet of horses, is noisy and unpleasant for all descriptions of light traffic. The setts for paving purposes should be 4 in. across and have a depth varying from 5 in. to 8 in. The length should be equal, not exceeding 12 in., and should be laid so as to break joint with their lengths across the road. The foundation should be formed of 6 in. of concrete and the setts should be bedded in 1 in. thickness of asphaltic concrete or chippings and cement, and on completion thoroughly rammed to a level surface and grouted with hot liquid asphalte until the joints are quite full. Sandstones of good quality make a less slippery pavement, but are not so durable as granite. A comparatively new method of sett paving has been introduced into England called the "Durax" system, in which the best descriptions of stones are arranged in a manner so

as to afford the maximum amount of comfort combined with durability and efficiency, while its cost will favourably compare with most of the forms of pavement having far less wearing qualities. The "Durax" system of armoured roads consists of Durax cubes, which are machine-made, so as to assure the closest joint between the cubes of stone. These are laid side by side in segmental rows on a solid foundation and bedded on sand. The pavement thus presents the appearance of Mosaic work laid in a series of segmental curves. The traffic in passing over this form of road is distributed over a larger area than would be the case in an ordinary sett-paved roadway, and both noise and wear are reduced, and many of the former objections to the stone pavement are eliminated. It is very durable and comparatively inexpensive to adopt, the initial cost comparing favourably with that of soft wood paving and possessing a much longer life. This system of paving has been much used in Germany, Austria, and Italy, and highly satisfactory work has already been carried out within the borders of this country. R. H. B. & F. L.

Road Watering.—**Necessity and Objects—Methods—Types of Apparatus—Cost—Dust Palliatives.**

The Public Health Act, 1875, s. 42, gives powers to the local authority to themselves undertake or contract for the proper watering of streets for the whole or any part of their district.

Necessity and Objects of Street Watering.—Street watering is a necessity in dry weather to lay the dust caused by the disintegration of road surfaces by traffic and other means. Also paved roadways are apt to get very slippery in hot weather, and by the action of the heat the pitch in the joints becomes melted and runs out. Added to this the great heat thrown up from paved roads is very distressing to vehicular and pedestrian traffic. Systematic watering alleviates these defects to a certain extent and makes the air more cool and congenial. Many of the principal thoroughfares in large cities and towns are thoroughly washed during the night, a practice which has great advantages from a sanitary point of view.

Objections. — Objections are sometimes raised, because watering, if not carefully carried out, creates a thin mud, which becomes dangerous to cyclists and others. Also excessive watering washes away the binding material and deteriorates the road surfaces.

Road watering is now being largely replaced by "tarring" of the surfaces with advantages from every point of view.

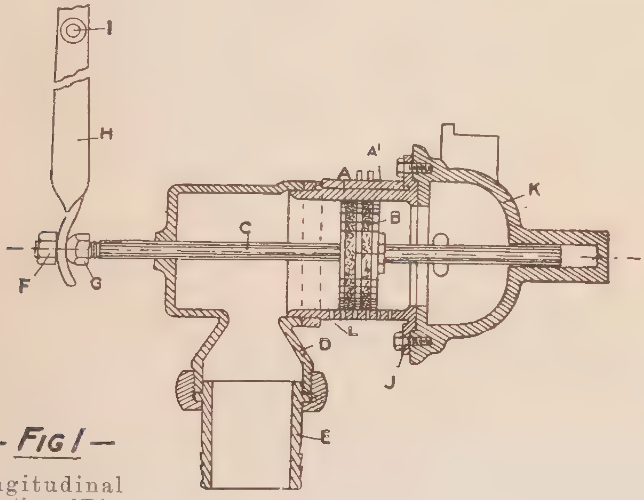
Methods.—There are two methods of watering roads, viz:—(1) by hand, in which a hose and reel or portable iron tubes are used; and (2) by vehicles, drawn either by horses or by steam. The former is very seldom used, most towns employing either horse-drawn vehicles or motor-vans. In Paris, however, and some of the London boroughs and certain provincial towns, the "hose-reel" is adopted. Hose-pipes are also attached to the fire hydrants in the streets and the water is delivered on to the road through a rose nozzle or other appliance. This sometimes proves to be objectionable in wide streets owing to the uneven distribution and the inconvenience to the traffic, but it is a great advantage in washing out paved markets and the adjacent streets.

Types of Apparatus.—Watering-carts can be fitted with "tell-tale indicators," which register the number of loads used during the day. These are useful in checking the driver's work, and also in keeping an account of the quantity of water used.

Distributors are now manufactured so that the supply of water on to the surface can be regulated to a nicety. One form of modern distributor is divided into four compartments, each of which is fed from the tank by a separate valve and pipe. This distributor is so constructed that by the use of the two upper compartments a lighter spray will be delivered on the surface than if the lower compartment were used. Any of these compartments may be used alone, so that either side of the distributor can be worked when passing vehicles or

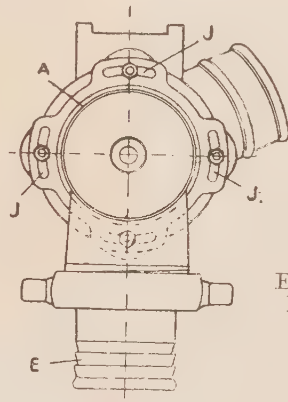
watering narrow strips. Willacy's & Greves rotary water-sprinklers are efficient means of distributing water in wide streets as well as streets of average width. Water distributed by these rotary machines is more evenly sprinkled than when a box arrangement is used, and there is, therefore, a saving in the relative cost. There are many makes of sprinklers on the market, but reference will only be made to the "Warwick sprinkler" (see Figs. 1, 2, and 3).

A is a gun-metal cylinder perforated with holes for about two-thirds its circumference for the distribution of water. *B* is a piston regulating the supply of water from the connecting head *K*. *C* is the piston rod, operated by lever *H*, connected to the foot levers on front of vehicle. *D* is the flanged pipe for flushing gullies, &c., and can either be left plain or screwed and fitted with union *E* for hose.



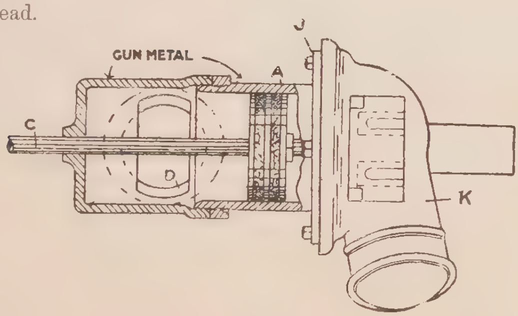
— *Fig 1* —

Longitudinal Section of Distributor Head.



— *Fig 3* —

End View of Distributor.



— *Fig 2* —

Longitudinal Section of Distributor Head on a Line at Right Angles to Fig. 1.

The foot lever is arranged so as to operate the piston *B* in four distinct movements, either exposing two, four, or six rows of holes *L*, in addition to the flushing pipe *D*.

The width of spread is controlled by a slide A^1, embracing the cylinder for about a third of its circumference to cover up the holes more or less as desired.

When the flushing valve is in use this slide is dropped to its fullest extent so as to prevent the water being distributed in any but a downward direction.

By releasing the studs *J*, the distributing head may be adjusted to distribute the water more or less in the centre of the road, and, if desired, the centre of the road or tramway track may be left dry for a space of about 6 or 7 ft.

The distributor is supplied, attached to every possible form and size of vehicle, with circular or rectangular tank, and mounted on either two, three, or four wheels.

The van is fitted with a branch outlet pipe on the underside which is connected to the distributing heads by means of india-rubber pipes.

There are no valves or fittings of any kind inside the tank.

There are two valves only, each of which gives ten or more variations in the width and grade of spread and operates the flushing connections, according to the distance the valve is opened. This is all worked by means of foot or hand levers, working from the driver's seat, without the driver losing control of the horse by leaving his seat.

The water is distributed at right angles to the direction in which the van travels, thereby obtaining a much more effective distribution of the water than with an ordinary van, Fig. 4.

Cost.—In busy and wide thoroughfares, where traffic is heavy, motor watering-vans have been found economical. Experiments have been made in various towns to ascertain the quantity of water required for road watering during the dry summer season, and it has been found that with valves at convenient distances apart a water-cart will water from 25,000 to 35,000 square yards four times a day. A gallon of water will cover an area of four square yards of road surface. Much time is lost in travelling to and from the hydrants, stand posts, or valves, and it will be found that, on suitable gradients, a four-wheeled van which has a capacity of 350 to 450 gallons will perform more work in a given time than a two-wheeled cart which has a capacity of 225 to 250 gallons. It has been found that the difference in the work done is on the average at least 25 % in favour of the four-wheeled van. Motor-driven watering-vans, which carry a much larger quantity of water than horse-drawn carts or vans, are, as already mentioned, used in some towns with satisfactory results. Figures giving comparative cost of these three systems, *i.e.*, horse-drawn vans, horse-drawn carts, and motor water-vans, are difficult to obtain, but the following information from the "Municipal Engineer's Specification," Vol. I., p. 9, will prove useful:—"In Bradford, watering by means of ordinary water-carts costs 6½*d*. per load, or 4*s*. 10*d*. per mile of road. Watering by hand with hose costs 4*s*. 5*d*. per mile of road, and watering by means of a revolving disc van costs 5¼*d*. per load of 350 gallons, or 2*s*. 3*d*. per mile of road." "Santo Crimp gives the average cost of watering at 3·86*s*. per mile of road 8 yards wide." Road watering by means of horse water-carts and vans and motor water-vans in the metropolitan borough of Wandsworth works out at £39 8*s*. 6*d*. per

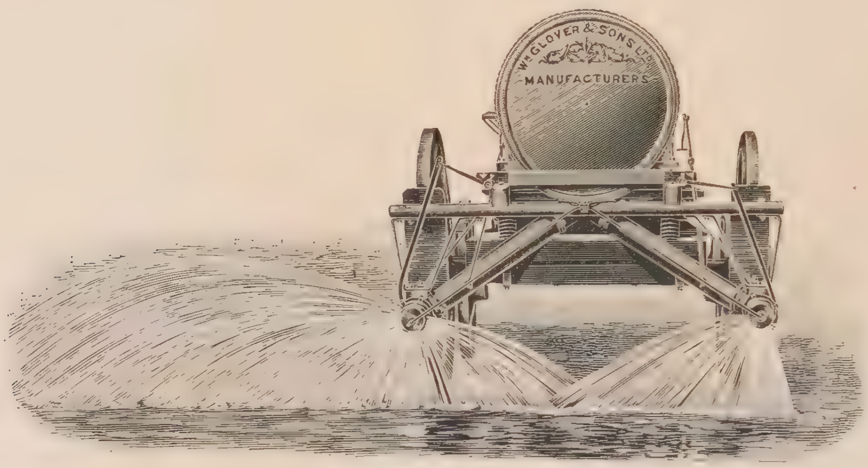


Fig. 4.—The Warwick Sprinkler.

mile of road *per year*. Motor-vans sprinkle at the rate of about ·192 gallon to ·078 gallon per square yard. H. P. Boulnois, in his "Municipal and Sanitary Engineer's Handbook," 1898, p. 309, gives the cost as obtained from Reading at 9*s*. 5*d*. per day covering a length of 2,981 yards double width of roadway. If the work is capable of being done in one width the length will be 5,962 lineal yards. This will give a cost in the former case of about 5*s*. 6*d*. per mile, and in the latter case of about 2*s*. 9*d*. per mile of roadway.

Dust Palliatives or Materials Mixed with the Water.—It is sometimes advisable, in order to successfully cope with the dust nuisance where special preventative measures have not been adopted, to add some form of binding material to the water used for sprinkling the surface of the roads. A large number of such preparations have been introduced during recent years with more or less success. Among them may be mentioned the following:—

Calcium Chloride Crystals. — These are placed in the water-van or cart and slowly dissolved in the water. A small quantity will be found sufficient if applied regularly. This chemical will dissolve in sea water as well as fresh water, and in districts where salt water is used for watering the roads it will be found doubly advantageous. It is, however, too slippery to be used upon hills.

Emulsifix.—This is a dust-layer or palliative when mixed with water. It contains emulsified tar, and it is claimed that its use saves two-thirds the cost of watering with fresh water. The material is only applied occasionally from seven to ten times during a dry summer, and on account of the small percentage of oil used each time, no ill effects appear, and sloppiness is thus avoided. There are many other dust-laying preparations on the market, but these are too numerous to refer to in detail in the present article.

Sea Water, the uses and objections to.—Sea water has been extensively used for street watering in several seaside towns with satisfactory results. It has been found that by its use as compared with fresh water (*a*) the surfaces of the roads remain damp for a longer period; (*b*) it hardens the surface of the road, forming a crust which prevents to a large degree the nuisance from dust; (*c*) a much smaller quantity is necessary, thereby reducing the cost, not only of watering, but of repairs to the surface; (*d*) it preserves wood pavements and makes them easier to cleanse; (*e*) it has also been contended by some that it retards the decomposition of refuse on the streets, thus preventing disagreeable smells. Among the objections to its use are:—(*a*) Damage is caused to the varnish on carriages; (*b*) the dust arising contains salt and is injurious to tradesmen's goods; (*c*) the road surface is, after several applications, covered with a coat of salt, and thorough washing and sweeping is necessary to the surface to remove this coating.

F. L. & R. H. B.

Rust Chambers.—Pockets or recesses provided at the bottom, or in bends of iron ventilation shafts, for receiving and collecting rust scales, and so preventing these from blocking the pipes.

Sand Filtration. (*See* "Filtration of Water.")

Sanitary Fittings.—This term embraces closets, baths, and other such appliances fixed within buildings. For details see under separate headings. Unless carefully selected and properly placed and fixed, sanitary fittings are liable to belie their name and to prove the more dangerous owing to their position in the interior of the house. In general, they should be as simple in construction and design as possible; the former in order that there shall be as little as may be to get out of order, the latter to promote cleanliness. Nooks and corners and all ornamentations, whether raised, sunk, or coloured, should be avoided, as they tend to harbour and hide dust and

dirt. All surfaces liable to be fouled should as far as practicable, be self-cleansing, and, if this is not possible, so arranged and constructed as to show the soiled surfaces and permit of their cleaning by hand. Particular attention must be paid to the overflows of fittings, which detail is the one most likely to prove a nuisance. These overflows are only occasionally flushed, rapidly become coated with filth, and are apt to give off musty and insanitary emanations. Most fittings in the past, and many at the present time, are so constructed that the overflow pipes are invisible and incapable of being got at, if at all, without the removal of bolts and screws which the average householder or maid is incapable of removing. The only overflows which should be tolerated are those in the form of an open weir, which will allow of the insertion of a brush for cleaning purposes, or the detachable trumpet overflows with which many baths, sinks, and lavatory basins are now fitted.

Soap dishes in lavatory basins, baths, and sinks, but more especially in the first-named, are also frequently improperly made. They often consist of sunk dishes drained into small inaccessible pipes through one or more small holes in their bottoms. The pipes leading from these dishes are inaccessible and rapidly give rise to nuisance due to decomposing deposits of soap. The holes are also apt to become clogged and to lead to the retention of water in the soap trays. For this reason undrained dishes should also be avoided. The soap trays to be preferred are those which drain through a small open channel into the basin or other fitting upon which they are provided.

Each fitting, whatever its nature or object, must be trapped as near as possible to its outlet by means of an efficient trap (*see* "TRAPS"), and as a general rule it is well to make use of only such fittings in which the trap is separate from the appliance proper; as, should it be necessary to remove the latter, the trap need not be disturbed, but may be left on the waste or soil pipe to continue its function of excluding foul air from the house.

The trap must be of the same or of a smaller sectional area than that of the outlet under which it is fixed, due allowance being made for the space obstructed by the outlet grating, where such exists. Were it larger the flow from the fitting would not be of sufficient volume to thoroughly cleanse it. In fixing the trap care must also be exercised to see that the overflow pipe from the fitting —where such is separate from the outlet—is connected to the inlet side of the trap (preferably above the level of the standing water), and not on the outlet side. Where the latter is the case the objects of the trap are frustrated, as foul air is able to enter the house through the overflow arm. When necessary the traps must be ventilated (*see* "SIPHONAGE").

The waste pipes of fittings which discharge at some point in the apartments in which they are fixed (such, for instance, as a housemaid's sink discharging into an adjoining slop-hopper, or a washtub discharging into a channel in the washhouse floor) need not be trapped, as there is obviously nothing to trap off. Nor need the waste pipe of a drip or draw-off sink be trapped if no fouled water is thrown into it, and its point of discharge is in the open air, such as over a roof or lead flat, and at some distance from any likely source of tainted air. It is, in fact, desirable not to trust to a trap in the case of such a sink, as there are frequent occasions on which the trap will contain but little, if any, water. It is only when the housemaid is careless, and permits the jug or bottle to be filled to overflowing, or does not properly close the tap, that such a trap receives water. The waste pipe may, however, be advantageously fitted with a flap-valve at its outlet in order to exclude draughts.

Sanitary fittings may be roughly divided into two classes, viz., (*a*) those for discharges consisting of purely waste water, and (*b*) those for discharges charged with excrementitious matter. To the first group belong lavatories, baths, and sinks; to the second, water-closets, housemaids' slop sinks or slop-hoppers, and urinals. Waste pipes

from the former must be disconnected from the drains by being discharged over gully traps, while soil pipes from the second group of fittings, being provided for the removal of excreta, &c., must be connected to the drains directly.

All sanitary fittings should be fixed in suitable apartments. Convenience must, of course, be studied. A slop-hopper, for instance, must be fixed in close though safe proximity to the bedrooms, as the carriage of slops to a distance—possibly up or down stairs—would involve unnecessary offence. The waste of time and exertion involved would also offer a temptation to empty the bedroom slops into the nearest bath or lavatory basin. Safety must not, however, be sacrificed to convenience. If a suitable apartment is not at hand one must be made or adapted, or the fittings altogether dispensed with. A cupboard or dark out-of-the-way corner is unsuitable for any sanitary fitting, as in such a position it would be sure to become offensive. The lighter and more airy the apartment, the cleaner and less offensive will be the sanitary apparatus. The apartment in which a sanitary fitting is to be fixed should, therefore, in the first place, be light and well ventilated. The former condition will render dirt and splashings visible, and thus insure their removal, and at the same time tend to prevent them, by enabling the user to see what he or she is doing. Thorough ventilation will maintain the purity of the aërial contents of the apartment. This ventilation, whenever possible, should be independent of that of the remainder of the house.

A room which provides the above conditions will usually also provide a second *desideratum*, namely, that one at least of its walls is an external wall. This is desirable in order that the waste or soil pipe may be immediately taken through the wall to the outside of the house. Such pipes, if avoidable, should not be fixed inside the house, as, however well made, they are liable to deteriorate or to be accidentally fractured.

The walls and floors in the immediate vicinity of sanitary fittings should always be constructed of impervious materials or rendered non-absorbent by being coated or covered with suitable material, such, for instance, as cement, tiles set in cement, slate, marble, or sheet lead. The actual materials made use of must necessarily be governed by such considerations as cost, the nature and purposes of the appliances and rooms, their positions, and similar questions, which may vary in each case, and which must be considered and judged as they arise. The great thing is to prevent the retention of such objectionable matter as may be splashed over and around the fittings. Woodwork should, for the same reason, be avoided in connection with fittings whenever possible. If it must be used the wood should be of a hard and close-grained nature. It should also be either painted or varnished.

G. J. G. J.

Sanitary Inspector, or Inspector of Nuisances.—The statutory title of Sanitary Inspector is held in London by virtue of section 108 of the Public Health (London) Act, 1891, and that of Inspector of Nuisances by sections 189 and 190 of the Public Health Act, 1875. The two titles are for practical purposes synonymous; that of sanitary inspector is the newest and more popular term. The development of the sanitary inspector's office has been contemporaneous with the growth of public health administration. The actual origin of the office dates back to the time of Queen Elizabeth, when an officer, called the overseer of the highways, and annually elected by the vestry or highway authority of the time, possessed power to deal with nuisances thought to be injurious to the health of the community. It was not, however, until the Public Health Act, 1844, was passed that any legislative attempt was made definitely to specialise the duty of inspection of nuisances. But in the Nuisances Removal Act, 1855, there is a clear recognition of the office, for by section 9 of that Act local authorities are compelled to appoint "sanitary inspectors." This important step was further emphasised in the same

year by the Metropolis Local Management Act, which, by section 133, provides that inspectors of nuisances shall be appointed to supervise scavenging, with powers to take legal proceedings, and their duties are clearly defined in other respects. The Public Health Act, 1875, was an amplification and codification of previous public health statutes, and the Public Health (London) Act, 1891, was designed to meet the special conditions of the Metropolis. These two last-named Acts give the present sanitary inspector his status in public health administration. The duties of the office are many and varied, the chief being described as follows:—by systematic inspection of his district to keep himself informed as to any nuisances therein; attend to complaints of nuisances or infractions of the law or by-laws; enforce regulations made in respect of offensive or noxious trades and manufactories; supervision and examination of food exposed, or in preparation, for sale for human food; seizure of unsound food and obtaining its condemnation by a court of summary jurisdiction; to collect samples of food and drugs for analysis, and to take proceedings against offenders; to supervise the execution of works ordered by the sanitary authority for the abatement of nuisance; enforce regulations for keeping animals in a cleanly state; prevention of nuisance by smoke; supervision of drains and sanitary fittings of dwelling-houses, work-places, &c.; testing drains; abatement of overcrowding; regulation of lodging-houses; supervision of the housing of the working classes; inspection of canal boats; inspection of and enforcement of regulations in respect of dairies, cowsheds, and milkshops; regulation of slaughter-houses, and maintenance of workshops in a sanitary condition, with proper temperature and ventilation. A most important part of their work also is that of dealing with notification of infectious diseases, removals to hospitals, disinfection of premises, and so on. Outside the Metropolis there is no statutory qualification for the office; any person can be legally appointed an inspector of nuisances under the Public Health Act, 1875. In London the sanitary inspector must possess definite qualification. By section 108 of the 1891 Act, since 1895, every sanitary inspector appointed is required to hold a certificate of competency from such body as the Local Government Board may approve, and such certificates are now granted by the Sanitary Inspectors Examination Board. The Royal Sanitary Institute also holds examinations for sanitary inspectors, and issues various certificates. In country districts the tenure of a sanitary inspector is generally for one year, with annual re-appointment under the 1875 Act. But under section 108 of the 1891 Act, the tenure of sanitary inspectors rests with the Local Government Board, which, by article 10 of a General Order dated 8th December, 1891, says, "Every Sanitary Inspector shall continue to hold office for such period as the Sanitary Authority may, subject to their approval, determine at the time of his appointment or until he die or resign, or be removed by such authority, or by the Local Government Board, or be proved to be insane." The London County Council now pays half the salaries of many sanitary inspectors engaged by the metropolitan borough councils, but this financial aid to local sanitary adminstration does not affect in any way the position or duties of the inspector. By article 14 of the Local Government Board Order, made under the 1891 Act, the salary of a London inspector is such as may be approved by the Local Government Board, which, however, has no power to direct what salary shall be paid. In England the salary of a sanitary inspector varies from £5 per annum in small rural districts to £350 per annum. The average in the Metropolis is £220. Scotch and Irish sanitary inspectors are appointed under different Acts, their tenure of office, qualifications, &c., varying also. The highest salary paid in Scotland is £600 per annum. There are about 3,000 sanitary inspectors in the United Kingdom, and of these probably a sixth receive salaries of below £30 per annum. In London, superannuation may be granted

to a sanitary inspector under 29 Vict. c. 31, while in some metropolitan boroughs, and also in some provincial cities, power to superannuate has been obtained by special Acts of Parliament which establish a contributory scheme of superannuation for municipal officers. But in most rural and urban districts the sanitary authority has no power to grant any superannuation. Women are now appointed as sanitary inspectors, or health visitors, mostly having special duties in regard to infant mortality, infant feeding, domestic inspection, &c. In districts where a number of sanitary inspectors are employed by the same authority it is the practice to appoint a Chief Sanitary Inspector, but in London the Chief Sanitary Inspector does not differ statutorily from an ordinary inspector; in urban districts the position is slightly different, as the 1875 Act gives power to "appoint an inspector of nuisances and such assistants." In rural districts the position is the same as in London, one or more inspectors being appointed. With the development of public health administration necessitated by increase of population in towns, urban areas, and metropolitan districts, sanitary inspection has become largely specialised, the duties of the inspector's office demanding knowledge of many widely different subjects, ranging from drain-pipes to meat. The special circumstances and conditions of districts govern the specialisation, the most common special inspectors being meat inspectors, food inspectors, district and general inspectors, canal boat inspectors, food and drugs inspectors, smoke inspectors, workshop inspectors, port sanitary inspectors, and so on. In London the inspector has statutory authority to serve preliminary notices on his own initiative, and afterwards to take further proceedings as instructed by the sanitary authority. In country districts the inspector has no statutory power to serve notices without first being authorised on his report in each case to the sanitary authority. In seizing meat, however, inspectors can act without special authority. An inspector has to produce his books at the request of the Medical Officer of Health, and, as far as the local authority decide by resolution, to carry out the instructions of the medical officer, but in the absence of such resolution the medical officer has no statutory power to give instructions to the sanitary inspector. The surveyor has no authority over the inspector, nor can such authority be given by the local authority. Sanitary inspectors are an organised class of officials. In 1883 the "Sanitary Inspectors' Association" was founded under the title of "The Association of Public Sanitary Inspectors," and was incorporated by licence of the Board of Trade in 1891 under its present title. The objects of this organisation are largely educational, but occasionally representations are made to various public authorities in the interests of sanitary inspectors as a whole, or in special cases. It was amalgamated recently with the National Union of Sanitary Inspectors.

C. E. A.

Sanitary Institute, Royal.—The Royal Sanitary Institute was founded in 1876 under the presidency of the late Duke of Northumberland, for the advancement of all subjects bearing on public health, and in 1888 it amalgamated with the Parkes Museum, which was also founded in 1876 as a memorial to Dr. E. A. Parkes, the first Professor of Hygiene at Netley. In the early days of these two societies, the Public Health Act, 1875, had only recently been passed, and there was great need for elementary instruction and information in the principles of hygiene, and it was this need that the Sanitary Institute of Great Britain (which was then its title) set itself to meet. One of the first steps taken by the Sanitary Institute was to establish examinations for local surveyors and inspectors of nuisances. The first examination was held in October, 1877, when eight candidates came forward. These examinations gradually gained in public estimation, and sanitary authorities began to recognise the advantage they afforded in guiding them in the selection of sanitary officials. The examinations

revealed the fact that candidates for appointment as sanitary officers had considerable difficulty in obtaining knowledge of the principles of sanitation, and the council established systematic courses of instruction suitable for these officers. The examinations, which had hitherto been held in London only, were, in 1889, extended to the provinces, so as to make them more accessible to candidates living at a distance. In the following year the training lectures for sanitary officers were also extended to the provinces, and arranged in conjunction with the county councils; and in the Public Health (London) Act the Institute obtained the insertion of a clause requiring all sanitary inspectors in London appointed after the 1st January, 1895, to hold a certificate of qualification. In 1892 arrangements were made for adding practical demonstrations to the courses of lectures for sanitary officers, and visits for the students were arranged to sewage works, waterworks, trade premises, and other places that would be instructive from a sanitary point of view. It was pointed out to the council, in the year 1895, that there were many persons who had no intention of becoming sanitary officers who desired to obtain a certificate from the Sanitary Institute, indicating their knowledge of sanitary science; the council therefore thought it desirable to arrange a syllabus, which, although not including many technical subjects that an inspector is required to know, goes beyond the scope of the inspectors' examination, as far as relates to practical sanitation. The examination is arranged so as to be suitable for foremen of works, builders, and those engaged in allied trades, managers of property, teachers and lecturers, and others requiring a thorough knowledge of practical sanitary science. In consequence of the report of the Royal Commission on Tuberculosis, attention had been directed to the important question of food inspection. There appeared to be no means available to sanitary inspectors for obtaining any information on this subject, and the council therefore organised, in connection with the lectures, demonstrations with regard to the inspection of meat followed by a practical examination, and special courses have been added adapted to the requirements of army officers and professional men who come up for the examinations.

Further courses of training and examinations have since been established by the Institute for school teachers, and for health visitors and school nurses, whose influence in forming a hygienic conscience in childhood can effect much in the advance of health of the nation. Examinations of the Institute are officially recognised by the Local Government Board and other public bodies. The Institute's activities extend to the Colonies, where branch organisations are being established. Series of lectures on sanitation in relation to the medical profession on the sanitation of industries and occupations, and on weather and climate in relation to health, have been arranged by the Institute from time to time, sometimes in co-operation with other societies.

The Parkes Museum, which is maintained by the Institute, contains a collection of typical appliances relating to sanitation and public health. It is used by the Medical Schools and Colleges of the London Hospitals for their classes for the Diploma in Public Health, and is recognised by the Science and Art Department in connection with their classes, and the class visits paid by the students to the museum may be counted as a class attendance for the purpose of the examination grant. The museum, besides being a most important adjunct to the work of the Institute, forms the basis of a large portion of the teaching in practical hygiene that is given in London. Visits are frequently made to the museum by representatives from the Colonies and the Continent, with the object of obtaining information for establishing or enlarging similar museums. The Institute has a large sanitary library which has been added to by the transfer to it of other similar collections, and now forms one of the best sanitary libraries in London. The Transactions of

the Institute were first issued to the members in 1879, and for many years consisted of an annual volume; afterwards it was thought desirable to give the information more frequently, and in 1894 they were issued as a quarterly journal, and in 1905 it was altered to a monthly publication.

Periodical congresses, attended by the members and representatives of public bodies, are held in different parts of the United Kingdom. In connection with these meetings, exhibitions of sanitary appliances are held. Conferences on special subjects have been convened in London from time to time. Meetings of the members for the deliberation on, and discussion of, subjects relating to public health are held throughout each year in London and in provincial centres, and are also arranged from time to time in the Colonies.

A special committee is appointed by the council to consider all Bills brought before Parliament that bear upon public health, and, on their recommendation, petitions and amendments are submitted to both Houses and to the supporters of the Bills. By-laws of the London County Council, water regulations, and other matters of public sanitary interest are carefully watched and discussed, and experiments and investigations are conducted to elucidate points under discussion. There is also an expert committee for judging and making awards to sanitary appliances exhibited at the exhibitions held by the Institute. These awards are made on a uniform system so as to serve as a guide to the public in selecting sanitary apparatus.

In the course of each year some 500 meetings are organised in order to carry out its various functions.

The various branches of the work are, in short:—The Museum, containing a collection of typical sanitary appliances; the Library; Students' Lectures and Examinations; the Monthly Journal of Proceedings; Meetings for Discussions; Congresses; Exhibitions; Research Work and Experimental Work; Parliamentary.

The Institute has carried on its work entirely without the aid of public funds, but a portion of the Berridge Bequests, amounting to £10,000, was allotted to the Institute, and some years later it had a legacy of £5,000 left by Mr. Rogers Field.

The aim which the Royal Sanitary Institute has before it is to produce a higher standard of health and the reduction of the death rate and sickness rate throughout the country. It seeks to accomplish this (*a*) by dealing with the question of the rearing of infants, their proper feeding, and the removal of the various causes which affect infant mortality. (*b*) By endeavouring to secure the purity of the milk supply and the food supplies, especially meat. (*c*) By advancing measures for the better housing of the working classes, and also by promoting a proper use of materials, sanitary appliances, and drainage arrangements in better class houses. (*d*) By dealing with the various causes of preventible diseases and the proper isolation of infectious diseases, especially the question of tuberculosis.

By means of its pioneer work in teaching and examination, the discussion of various questions and problems that arise, and other practical efforts, the Institute has become an important factor in the advancement of hygiene and public health in Great Britain and the Colonies, and its steady growth is an indication of the increasing attention given to this science. E. W. W.

School Hygiene embraces a due regard to every circumstance that may react for good or evil upon the physical and mental health and development of the school child, Thus the site and construction of the school premises, the ventilating, lighting, warming, and cleaning of school class-rooms, cloak-rooms, corridors, and dormitories, the provision of suitable school furniture, and of washing, water-closet, and urinal accommodation, must all insure the best possible hygienic environment for the scholars, and present an object lesson of cleanliness and of scrupulous

regard to all sanitary demands. Regard for the personal hygiene and physical development of the scholar is no less important; and the prompt detection of physical defects and of communicable and other disease is of prime concern. The demands of school hygiene also embrace the teaching and training of scholars in the laws of health, in order to promote the formation of healthy habits and the "health conscience" which, along with the practical advice given, will fit them to lead healthy lives and to guard the health interests of their offspring. Although Hygiene is not yet taught as a subject in our elementary schools, the Educational Code now definitely "recognises" one important branch of it, namely, Cookery and Housewifery. These matters, including infant care and feeding, should certainly be constituted a compulsory practical training course for the older girls, as suggested by the Royal Commission on Physical Deterioration. The extent to which the home influences and the school influences, respectively, are responsible for physical defects and the prevalence of diseases among school children is a matter which may ultimately be determined, but for the present it is imperative to avail ourselves of the unrivalled opportunities which school attendance presents for the detection of these disabling conditions. There can be no gainsaying that even at the present day the school remains the chief centre of infection among the community. The circumstance that the most susceptible units of the population are daily assembled in close contact is responsible for this; and the closest co-operation of the school teachers, medical inspectors, and medical officers of health is necessary to meet the legitimate demands of parents that school attendance shall be made as safe for the children as it is possible to make it. The problem of promoting the physical and moral hygiene of the community does not grow easier day by day with the increasing concentration of population of large urban communities, and all are agreed that there exists a sad need for the general raising of ideals among the people. It is upon school influences that we must mainly base our hope and expectation of future improvement in this respect. It is not, however, on these grounds alone that the State has done so much to promote school hygiene. The fact has long been recognised that the fullest regard for the bodily health of the child is necessary to obtain the best mental reaction; and so school methods, carefully designed to meet the physiological demands of a mentally and physically developing child, determine educational efficiency; thus it is realised that school hygiene is necessary for the development of the best type of citizen—the best mentally, the best morally, and the best physically. Systematic courses of instruction for teachers have accordingly been arranged by many educational authorities, and the increasing efforts of the London County Council to meet this need in London during the past few years is a noteworthy sign of the times. Moreover, the recently issued set of regulations of the Board of Education, in reference to school teachers, introduces for the first time a compulsory hygiene course and a compulsory examination in hygiene for all students in training colleges who intend to be teachers in elementary schools. The medical inspection of school children which is now in operation throughout the country may also claim both physical and educational merits. It aims at detecting and removing physical disabilities which in no small measure determine physical health and development, and it is an additional method of endeavouring to put the school child into the most suitable state for his training. Moreover, it is but the logical consequence of the State taking over the school education of the child from the civic standpoint that the State requires efficient citizens and the child is not the property of the parent alone. In the scheme of medical inspection the teachers are generally asked to select those children for special medical examination who show any marked signs of departure from the normal; loyally to assist generally in the larger scheme and organisation of medical inspection; and by exercising a tactful influence

over parents to assist in obtaining a remedy for their children's defects. It need hardly be said that the teachers have responded loyally to these demands. To whatever extent medical inspection may lead to the detection and alleviation of physical defects in school children, to a corresponding extent will children gain in general health and development, better results will be obtained from the teaching at school, the more healthy and physically fit child will be less a drag upon the resources of the family and the State, and posterity will benefit from a healthier stock. The results of the work already undertaken in this country, of course, vary with the schools inspected, but the figures range from 10 °/₀ of unfit children in the better class schools to more than 30 °/₀ in schools drawing scholars from the slums of large cities. Supplemented by trained school nurses and health visitors, who will penetrate into the more necessitous homes, medical inspection will develop into a potent educative force in preventive medicine and in raising the level of social well-being. H. R. K.

Separator, Rain-water.—An appliance made use of for discarding the first flow of water from roofs and other surfaces where rain-water is collected for storage and use; this portion of water being always more or less polluted by the washings of soot, bird excrement, and other impurities. The apparatus consists of a vessel into which the rain-water is directed before passing into the storage tank, &c., so arranged that the first portion of the water is collected and emptied to waste so soon as the chamber provided for that purpose is full. This water having been tipped out, the remainder of the rainfall is allowed to enter the storage tank. When the flow of water has ceased, the vessel in which the soiled water is collected returns automatically to its original position.

Septic Tanks. (*See* "Sewage Disposal.")

Settling Tanks. (*See* "Sewage Disposal.")

Sewage and Effluents, Analysis of.—**Sampling — Analysis—Total Solids — Organic Matter — Albuminoid Ammonia — Products of Oxidation—Standards of Purity for Effluents.**

Sampling.—The analysis of sewage and sewage effluents is undertaken in order to ascertain the percentage purification produced by the process employed, or proposed to be employed, in treating the sewage. Effluents may also be examined to ascertain whether they pass a given standard, whether they vary according to modifications of treatment, or to learn whether an effluent which is satisfactorily treated by a given plant in times of normal flow is brought to the required degree of purification when the volume of sewage rises above the normal. In sampling sewage several points have to be considered, the most important of which is the great variation in the quantity and quality of the sewage at different times during the day and night. There is, of course, also a very great difference in the quantity and quality of the sewage according to the rainfall, and again the season of the year and the temperature have a great effect on the degree of decomposition which the sewage may have undergone on its way to the sewage works. There are naturally also minor causes which may produce considerable temporary alterations in the sewage, such as the flushing of the sewers, washing the streets, the discharge of accumulations of liquor from breweries, tanneries, paper factories and the like. The quantity and composition of town sewage varies from hour to hour. The strongest and most polluted sewage comes from the houses from about 8 to 10 in the morning, and the time taken for this to reach the works will depend on the distance and the fall. After 10 in the morning the liquids and solids entering the sewer are more diluted, and in the evening and night time the volume and the impurities are both very much reduced. As the bulk of the sewage varies, so must the bulk of the samples that are being collected, and samples should be taken hourly or half-hourly and mixed, and they should be placed in a bucket kept cool

with ice. It will generally be found necessary to break up the solids by a plunger, which may be made by nailing a disc of tin, perforated with holes, on to the end of a broom-stick. If the analyses are being undertaken with a view of learning the percentage purification attained by the process of treatment in use, samples of the effluent may be collected at the same time, taking as above mentioned hourly or half-hourly samples, in proportion to the volume of flow from time to time. By starting to take the samples of the effluent at a given time after the sampling of the crude sewage is begun, it may be possible to obtain representative samples of the crude sewage and effluent which actually correspond—that is to say that the effluent is actually identical with the crude sewage as the samples were taken from. In any case there ought to be little difference between the chlorine figures of the crude sewage and the effluent (both being determined on mixed samples after filtration through filter-paper). If the chlorine figures do not correspond very closely it brings us to the immediate conclusion that the samples of crude sewage and effluent are certainly not identical or strictly comparable, while if the chlorine figures do correspond we cannot conclude for certain that the samples are comparable, though they are probably so. Should there be a discrepancy of more than 1 grain of chlorine per gallon, the samples should not be taken as representative, and should be discarded, or the results should be calculated to a common chlorine standard, and only employed as part of a series extending over several more days. In any case, the sampling should be continued over a period of three days of normal (dry weather) flow, and if storm-water has also to be treated, as is generally the case, a second series of samples (extending over three days) should be collected as described above, during rainy weather, and submitted to analysis in the same way. In analysing sewage, partly-treated sewage, or sewage effluent, it is, as has already been mentioned, of the greatest importance to make the analyses as soon as possible after the collection of the samples, which should be kept cool in ice. It will readily be understood that such samples, containing, as they always must, great numbers of active bacteria in a liquid containing organic matter in process of breaking down and alteration, are far more liable to undergo rapid alteration in composition than potable waters, which contain far less organic matter and comparatively few bacteria. The rate at which this alteration will proceed in sewage and effluents is well shown by examining a fresh sample and repeating the analysis after a couple of days.

Analysis.—The analysis of sewage, partly treated sewage, and effluents is carried out very much on the same lines as a water analysis, except that it is necessary to use different quantities for certain of the operations. The estimations which it is usually customary to make are as follows:—

Total Solids may conveniently be estimated on an amount varying from 100 to 250 c.c. Mineral Solids are obtained by cautiously igniting the total solids and recarbonating, as in water analysis. The Loss on Ignition is ascertained by subtracting the mineral solids (re-carbonated) from the completely dried total solids. The loss on ignition is a valuable figure, but, as it is liable to vary very much in the crude sewage, an average of several samples should be taken. In partially treated sewage it will vary less, and in effluents it is even more constant still, and regular determinations are of great assistance in learning whether the treatment is uniform and successful.

The Chlorine Estimation is carried out as in water analysis, except that it is best to remove suspended matters first, by filtration, and if the water is alkaline or acid it should be neutralised before titrating with the standard silver nitrate solution. The standard silver solution should be kept in a brown bottle and placed in a dark cupboard when not in actual use. The value of the chlorine estimation lies chiefly in the fact that by its determination we are able to identify an effluent with the sewage it was produced from. That is to say,

if in a series of sewage samples and samples of effluent the average chlorine-contents are the same, or very nearly the same, we know that the effluent in all probability corresponds to the sewage, and, therefore, comparisons to ascertain percentage purification may be logically made, whereas if the chlorine figures exhibit a sensible difference such a comparison might, and probably would, be erroneous. It is hardly necessary to say that the chlorine figure is quite unaffected by any process of treatment (short of adding chlorides), and, therefore, any chlorides present in the raw sewage remain throughout the treatment and appear in the effluent neither diminished nor increased, except that a "smoothing" or equalising action takes place as the richer sewage that comes in the morning becomes gradually mixed with the diluted portions that come in the afternoon and night. It will be clear that a high figure for chlorine in a sewage will usually indicate a strong sewage, and in the same way an effluent which gives a high figure for chlorine was probably produced from a strong sewage; but whereas a high figure for chlorine in a potable water would be a bad sign, a high figure for chlorine in an effluent has no significance beyond that mentioned above.

Organic Matter.—The organic matter in a sewage is partly in solution and partly in suspension. Both of these are more or less accurately measured by the estimation of the loss on ignition previously mentioned. It is, however, customary to estimate the "oxygen absorbed" and albuminoid ammonia, which taken in conjunction afford valuable means of defining the organic matter present. In a liquid so much richer in organic matter than an ordinary potable water, it is necessary either to use different standard solutions to those employed in water analysis, or to work on much less quantities.

For the determination of The Oxygen Absorbed in sewage and effluents, it is convenient to use 100 c.c. of sample, and a standard permanganate solution of double the strength usually employed—care must be taken to add more permanganate if the colour becomes pale. It is best to adopt the 4-hour period for the permanganate to act on the organic matter, but even then a great deal of organic matter will remain totally unaffected. For example, particles of straw, undigested muscular fibre, and the like, are almost entirely unchanged. It would probably be better to employ one of the hot moist combustion processes which are in favour abroad, but which do not appear to be much used in this country. The amount of "oxygen absorbed" in a fresh crude sewage is very variable and may be from as low as a grain per gallon up to 10 grains or more. In a well-treated effluent there should be a reduction of 70 to 80 % on the figure for oxygen absorbed.

Albuminoid Ammonia.—This is determined, as in a potable water, by distillation with alkaline permanganate. Some workers prefer to operate on as small a quantity as 5 or 10 c.c. and to dilute it to 500 c.c. But it is better to work on 500 c.c. and (having removed the saline ammonia by distillation in the ordinary way) to collect all the albuminoid ammonia in a flask, and, instead of Nesslerising, to titrate the ammoniacal distillate with standard sulphuric acid, using cochineal as an indicator. As the saline ammonia has to be distilled off it may be estimated, and it will be found that whereas a crude sewage may contain from 2 to 6 grains per gallon, a well-treated effluent will rarely contain as much as 1 grain. At the same time the amount of saline ammonia in a sewage or an effluent is a matter of comparatively small importance. The albuminoid ammonia on a crude sewage is rarely more than 1 grain per gallon, and in an effluent is about 0·1, but should not be more. As mentioned before, in the "oxygen absorbed" process some of the organic matter may escape complete decomposition, but this is not the case in the estimation of albuminoid ammonia, as the energetic action of the permanganate in presence of alkali and the prolonged boiling may be relied on to

decompose any organic matter and to liberate as ammonia any combined nitrogen that is present.

Products of Oxidation.—When sewage is treated most of the suspended matters are removed either by natural sedimentation or by precipitation, or are mechanically detained in filter media. The oxidisable matters are altered and the nitrogenous matters are converted into nitrites and nitrates, while the non-nitrogenous matter is probably chiefly converted into carbonic acid gas, marsh gas, &c., and to a considerable extent escapes into the atmosphere. There is, therefore, no means of ascertaining in an effluent what has become of the non-nitrogenous organic matter which was originally contained in the raw sewage, but in the case of the nitrogenous matter a considerable proportion is oxidised to nitrates, and the estimation of nitrates should always be made in effluents, as the presence of a fair proportion of nitrates is most important as showing that true purification has been effected. Crude sewage very seldom contains any nitrates or nitrites. They may begin to appear at some point in the process, but they are always present in a properly purified effluent. As a rule the oxidised nitrogen in an effluent is all present as nitrate, only traces of nitrites being present. It is as well to test for the presence of nitrites (as directed under the "Analysis of Water"), but it will be very rarely necessary to estimate them. An effluent will yield the reaction for nitrites if it is kept for a few days in a closed bottle before analysing, but it very rarely yields any reaction for nitrites when fresh. The estimation of nitrates may be carried out as described under "Water Analysis," and the phenol-sulphuric acid method will be found to give satisfactory results.

Standards of Purity for Effluents.—As soon as it became customary to treat sewage, those engaged in its treatment naturally desired to know whether the effluents they produced were satisfactory, and also how their results compared with those obtained at other places by similar or different methods. Probably the appearance (colour and freedom from suspended matter) and absence of smell were the characters that were considered in early days. Later on it became the practice to place samples of the effluent in open and closed bottles and to note the appearance and smell after keeping for some time. If the samples remained sweet as regards smell and did not putrefy they were considered satisfactory. If a green growth occurred, it was (and is) regarded as a favourable sign. Such a growth is due to harmless algæ, and is unlikely to develop except in a fairly well purified effluent. At a later date, when the science of bacteriology began to receive attention, it became customary to incubate samples of effluent, that is, to place them in a chamber constantly maintained at blood-heat, and to note whether they remained sweet or suffered decomposition. As the science of bacteriology progressed it became apparent that the older methods of sewage treatment, which aimed chiefly at the removal or precipitation of the suspended matters, did not produce a sufficient effect on the organic matter in suspension, which passed on throughout the process and appeared in the effluent and caused it to "go bad," or suffer a secondary decomposition, accompanied by smell and by the growth of sewage fungus in streams into which the effluent discharged, at the same time often causing the death of fish in such streams where the volume of the effluent was great enough to destroy the "dissolved oxygen," without which fish cannot live. Later on it became customary to examine the number and nature of the bacterial population of sewage and effluents and to analyse sewage and effluents. It is now known that whereas sewage contains vast numbers of many different species of bacteria, effluents usually contain far fewer, and that even if disease bacteria exist in a sewage (such, for example, as the drainage from a typhoid hospital), it is very seldom that they can be isolated in the effluent, and, moreover, that the number of cases wherein disease is contracted from an effluent are so rare as to

lead to the conclusion that the disease bacteria in sewage must to a large extent be destroyed either by the other bacteria with which they are associated, or by some chemical effect of the various treatments in general use. It eventually was recognised that a chemical analysis was more useful than a bacteriological examination in showing whether a given sewage treatment was effectual. Putting the sewage problem into the simplest terms, the question before authorities resolves itself into this: How to treat their sewage in the cheapest manner consistent with the production of an effluent which will not give rise to a nuisance. Various standards have been suggested, and some have been definitely adopted in certain districts. It will be obvious that an effluent that is to be run into the sea or into a large river, which is not used as a source of drinking water, need not be as pure as one that has to be run into a very small stream, or a river from which a water supply has to be taken further down its course. The question of standards of purity for effluents was discussed at a meeting of the Society of Public Analysts, when a paper on this subject was read by the present writer in 1898, and various opinions were expressed by well-known analysts. The report of the paper and the discussion will be found in the *Analyst* for 1898, page 198. At this time the writer laid stress on the point that a properly purified effluent should conform to a standard expressed in figures showing the absence of more than certain quantities of "oxygen absorbed" and albuminoid ammonia, and that there should be present not less than a certain proportion of nitrates. These figures were founded on the analyses and observation of a large number of effluents, which, while they conformed to the suggested standard, were found to keep well, in open or closed vessels, without suffering putrefactive changes. Various "standards of purity" for effluents have been proposed, and some have been adopted, by bodies such as the Thames Conservancy, the Derbyshire County Council, &c. The Mersey and Irwell Joint Rivers Board's standard, which is a typical one adopted by other rivers boards, requires the following: Oxygen absorbed in 4 hours at 80° F. = 1 grain per gallon; albuminoid ammonia = 0·1 grain per gallon. All the standards are designed to secure the same result, namely, the production of as good and as uniform an effluent as possible.

C. G. M.

Sewage Disposal.—**Object of Purification and Composition of Sewage—Standards of Purity in Effluents—Screening, Detritus, and Sedimentation Tanks—Septic Tanks, and other Forms of Tank—Chemical Precipitation—Contact Beds—Percolating Beds—Removal of Suspended Matter in Effluents—Treatment on Land—Selection of a System of Treatment.**

THE OBJECT OF SEWAGE PURIFICATION is the removal of the suspended matters and the complete oxidation of the organic matter and ammonia in solution. In the treatment of sewage on land and on filters the process of oxidation is now believed to be mainly of a biological nature, but although a large amount of experimental and research work has been done, there are many scientific points connected with the purification of sewage which still require explanation. Provided the necessary expense is incurred, it is possible to carry the work of purification to any degree required either upon land or on specially prepared bacteria beds, and in both cases the work done is effected chiefly by the activity of various micro-organisms.

THE COMPOSITION OF SEWAGE differs widely in different localities. When of average strength it contains about 100 grains of solid matter per gallon, of which about one-third is in suspension and two-thirds in solution. The mixture usually consists largely of saline matter in solution, with nitrogenous and carbonaceous organic matter in solution and suspension, and varying amounts of sand, road grit, or other mineral matters. The strength of a sewage has necessarily an important bearing upon the nature of the treatment required for its purification, and since the process is largely one of indirect

oxidation through the agency of bacteria, the amount of oxygen required for bringing about its complete oxidation should be ascertained. This splitting up of the organic matter by the action of living organisms has been termed "bacteriolysis."

The *quantity of sewage* per head of the population to be treated daily varies considerably in different districts. It depends upon the water supply, the nature of the district, whether residential or trading, and upon the water-tightness or otherwise of the sewers. About 30 to 40 gallons per head per day is a common amount, but in some cases the quantity may rise to 50 or 60 gallons, according to local circumstances.

Standards of Purity.—Before proceeding to consider the various means adopted for purifying sewage it will be well to refer briefly to the question of the standard of purity desired. Although no fixed standard is, or could be, advantageously recognised as universally applicable, it is nevertheless needful to have in mind a safe standard for average conditions as a guide in checking the results obtained in any given case. Analytical results are sometimes recorded in grains per gallon, and sometimes in parts per 100,000. For purposes of comparison by conversion it should be remembered that 1 lb. avoirdupois = 7,000 grains, and 1 gallon of water = 70,000 grains, so that 7 grains per gallon = 10 parts per 100,000. Thus to convert grains per gallon to parts per 100,000 divide by 7 and multiply by 10, or conversely to convert parts per 100,000 into grains per gallon multiply by 7 and divide by 10. In comparing analyses of sewage effluents with the crude sewage it is important to remember that the chlorine figure serves as a useful guide to the strength of the sewage, and that no process of purification can remove it, so that the amount present before and after purification should bear close comparison. If they do not so correspond the effluent will have been obtained from a weaker sewage, thus showing an apparently greater percentage of purification by the treatment than is actually the case. A sewage of average strength contains from 10 to 12 parts chlorine per 100,000, but this depends largely upon the quantity in the water supply and manufacturing wastes entering the sewers. The chlorine itself is not important, and it is not necessary that it should be removed, but the amount present should be ascertained for the above reasons.

Good sewage effluents should contain not more than 2 parts per 100,000 of organic matter in solution, and none in suspension; the albuminoid ammonia should be less than ·1 per 100,000 (·07 grain per gallon); the nitrogen in the form of nitrates (oxidised nitrogen) should exceed ·5 part per 100,000 (·35 grain per gallon); and the oxygen absorbed at 80° F. in 4 hours for good effluents should be less than 1·0 part per 100,000 (·7 grain per gallon). The larger the quantity of nitrates present the more thoroughly has the sewage been oxidised, and this is, therefore, the best indication of the work done on the percolating or contact beds in the last stage of purification. The free ammonia of itself is harmless, and is not of great importance. A simple but useful rough test of purity is to shake a half-filled bottle of the effluent vigorously for one minute, when all frothing should disappear in three seconds. Another good plan is to keep a sample of the effluent for a number of days in a stoppered bottle at a temperature of 80° F., under which conditions a high-class effluent will not give off any offensive smell. Another good plan easily adopted is to keep a few goldfish in a globe or aquarium with "effluent" as the only water supply. This should be changed daily, and if the fish live without signs of distress it proves the effluent to be well aërated with sufficient dissolved oxygen to enable the respiratory processes of the fish to take place in comfort.

In the fifth (1908) report of the Royal Commission on Sewage Disposal the Commissioners state that "an effluent can best be judged by ascertaining, first, the amount of suspended solids which it contains, and second, the rate at which the effluent, after the removal of the

suspended solids, takes up oxygen from water. In applying this test it is important that the suspended solids should be removed and estimated separately. For the guidance of local authorities we may provisionally state that an effluent would generally be satisfactory if it complied with the following conditions:—(1) That it should not contain more than 3 parts per 100,000 of suspended matter; and (2) that, after being filtered through filter-paper, it should not absorb more than:

(*a*) ·5 part by weight per 100,000 of dissolved or atmospheric oxygen in 24 hours.

(*b*) 1·0 part by weight per 100,000 of dissolved or atmospheric oxygen in 48 hours.

(*c*) 1·5 part by weight per 100,000 of dissolved or atmospheric oxygen in 5 days.

Methods of Purification.—Turning now to the principal methods in use for the purification of sewage, these may be broadly classified in two divisions, viz.: (1) Processes for preliminary clarification, and (2) methods for the final oxidation of the impurities contained in the clarified liquid. The first stage of the treatment is carried out by means of screening, sedimentation, precipitation, either with or without chemicals, and by liquefying in the septic tank. The second stage, or oxidation process, may be accomplished by land treatment, either in the form of broad irrigation or land filtration, and by contact beds or percolating filters. Other, but less widely adopted, means of disposal are the dry-earth system, as in Eastern countries, sea-disposal, evaporation, and electrolysis.

Screening.—Coarse screening is essential upon arrival of the sewage at the works, whatever process may be subsequently followed. Its object is to remove the grosser suspended matters only, such as paper, rags, orange-peel, sticks, &c. Various classes of screens are used, including hand-screens in small works, automatically cleansed screens of a variety of design, and rotary power-driven screens for the larger undertakings. Fine screens choke readily, and the cost of cleansing is usually too great to justify their introduction.

Detritus and Sedimentation Tanks.—A detritus or grit tank is generally necessary for the purpose of intercepting the heavy mineral matter in the sewage, such as grit, sand, and road detritus, especially if the district is a hilly one, otherwise this material soon accumulates in the septic or sedimentation tank and increases the labour of removal. A detritus tank is obviously the more necessary where a town is sewered on the "combined system," owing to the greater proportion of grit in the sewage. The velocity through a detritus tank should be sufficient to carry forward the suspended organic matter, but just slow enough to allow the grit to settle to the bottom of the tank for daily removal. Two shallow tanks (Fig. 1) of a size capable

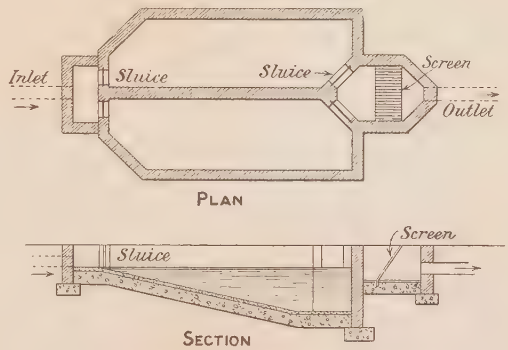


Fig. 1.—Detritus Tank.

of giving a velocity of about 30 ft. per minute to the sewage may be used and cleared alternately. For very small works, where regular labour is limited, it may be found more convenient to allow all the solid contents of the sewage to go forward to the sedimentation tank. A certain proportion of grit in sludge is found to assist the work of pressing and drying where these processes are carried out.

The term sedimentation tank is used more especially in connection with tanks in which sewage is allowed to settle without the aid of specially added precipitants, whilst the expression precipitation tank implies the use of chemicals or other precipitants to assist the settlement. Some sewages are very difficult to settle, such as those containing wool scouring liquor, tannery and brewery wastes, and to obtain a good tank effluent the deposit

must be removed after every first or second filling. Fermenting deposit several days old gives off gas, which rises and carries up the suspended matter with it, and thus greatly deteriorates the quality of the effluent. Sedimentation tanks, if worked so as to keep the sewage contents "fresh," give rise to little or no nuisance from smell. (*See also articles* "Precipitating or Settling Tanks," "Ives' Tank," "Dortmund Tank," "Candy Settling Tank," "Absolute-rest Tank," "Dundrum Tank," and "Cosham Tank.")

but it had no considerable practical application until proposed for the city with which Mr. Cameron was then connected. At first it was put forward that the septic tank solved the sludge difficulty, that it destroyed the pathogenic bacteria in the sewage, and that the tank-liquor was more easily oxidised than the effluent from an ordinary sedimentation tank. These claims, however, have not been substantiated by the test of longer experience. It is well known that all the organic solids are not digested by the septic tank, and that

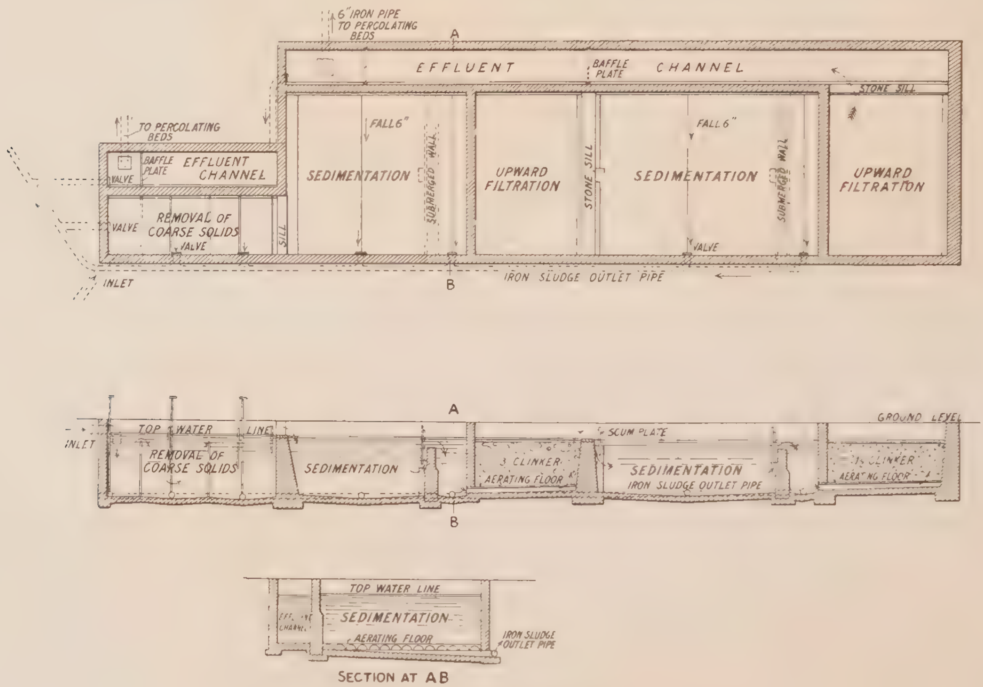


Fig. 2.—Preliminary Preparation Tank (*see* p. 403).

Septic Tanks.—The object of the septic tank, as introduced by Mr. Cameron, City Surveyor of Exeter, in the year 1895-6, was "to bring the sewage into such a condition by arresting the solids in suspension as to make the filtration on artificial filters practicable; at the same time taking advantage of the solvent action that goes on in the arrested solids, so as to make the quantity of deposit or sludge as small as possible." This idea of digesting solid sewage matter by passing it through a sealed tank was not new,

the amount varies according to the character of the sewage. At Birmingham the suspended matter digested or converted into gas is put at only 10 °/₀, Leeds 30 °/₀, Manchester 25 °/₀, Sheffield about 33 °/₀. With a domestic sewage of average strength a digestion of 25 to 30 °/₀ is probably the maximum likely to be realised. Little or no improvement is experienced in the bacterial condition of the septic tank effluent as compared with the crude sewage, neither is such effluent found to be more easily oxidised on the contact or percolating

bed in consequence of its passage through the tank. This is found to be the case with ordinary domestic sewages, and also with those containing "trade wastes," as confirmed by the experience of Huddersfield, Rochdale, Leeds, and other places. In fact, it is now generally recognised to be a mistake to carry the anaërobic changes too far, as by so doing the subsequent nitrification of the effluent is suspended. An "over-septicised" effluent is usually a very offensive liquid, owing to the increase of sulphuretted hydrogen produced, is invariably the cause of much trouble and litigation at sewage works through the nuisance thus set up, and is also very difficult to subsequently purify.

The quantity of solids in suspension in a septic tank effluent varies with the length of time the tank has been in use without cleansing, but the proportion increases seriously as time goes on, so that the quantity of liquid which can be satisfactorily oxidised on the aërobic beds decreases in proportion. On the average there may be from 15 to 20 parts solids in suspension per 100,000, but this amount may be doubled after 6 months' working.

With regard to the question of the proper periods for cleansing septic tanks, no uniform rule will be applicable, but the observance of the proportion of solids coming off in the tank liquor from time to time must be the guide. Should this percentage become too great the filters will suffer and the effluent therefrom deteriorate. In these circumstances the septic tank must be cleansed and the filters allowed time to recuperate. If a tank has been allowed to work for a long period of from 1 to 2 years, it is commonly found that the organic sludge has become fairly well digested and settled together containing from 80 to 85% of moisture, whereas the sludge from a tank cleared at short intervals may contain 10% more water. The sludge, upon removal from the tank, is oftentimes very offensive, especially where there is brewery waste in the sewage. Where it is desired to keep the liquor feeding the filters as uniform as possible, the fresh undigested part of the sludge at the bottom of a tank is sometimes not removed when clearing is undertaken, and further, if tanks are in duplicate, as they should be, a clean tank may be filled with septic liquor from an adjoining tank so as to hasten the full development of septic conditions in the newly cleansed tank. The latter method, as tested at Rochdale, is to be preferred to allowing sludge to remain in the tank as first mentioned.

One leading function of the septic tank is the equalisation of the variations in strength of the sewage delivered to the works and the production of a more uniform effluent for subsequent treatment. Another chief object is to bring about as large a settlement of digestion of suspended solids as possible, and upon this directly depends the choice of the most favourable rate of flow to be adopted. It is not possible, however, to lay down any hard and fast rules equally applicable to all cases as to the length of time the sewage should be subjected to anaërobic conditions in passing through the septic tank, as a good deal depends on the nature, temperature, and strength of the sewage to be dealt with. Regard must also be had to the length of time and distance the sewage may have travelled in the outfall sewer before arrival at the site of the disposal works. In the case of a long outfall having little fall, septic conditions may be well advanced, and the sewage will have undergone a thorough mechanical disintegration with bacterial decomposition and hydrolysis. Such conditions may well be contrasted with those which obtain in the case of a small works serving a village, mansion, or public institution, where the septic tank would be comparatively small and the sewage reaches the outfall in a thoroughly fresh condition within a very few minutes of leaving its source. In such circumstances the tank accommodation needs to be proportionately larger than that required for a large town, where the greater part of the sewage may be several hours journeying to the outfall.

In practice it would appear that the liquid

receives the necessary preparation for subsequent purification on aërobic beds by making the septic tank of such a size as will admit of the sewage sufficiently approaching a state of rest to allow of the precipitation of nearly the whole of the solids, and also by constructing it of sufficient depth to give space for retaining the same until the putrescible matter has been broken down. At Exeter, the home of the septic tank, storage approaching 2 days' flow was provided, and the past practice of the Local Government Board was to stipulate, first, for $1\frac{1}{2}$ days' dry weather flow, later for $1\frac{1}{4}$ days', and now for 1 day's flow. The tendency of the present time is in the direction of still further reducing the period of retention in the septic tank, and a storage, in duplicate, for one-half day's flow is doubtless sufficient in many cases. With Birmingham sewage, 24 hours' septic treatment is considered advantageous, but much depends on the strength of the sewage.

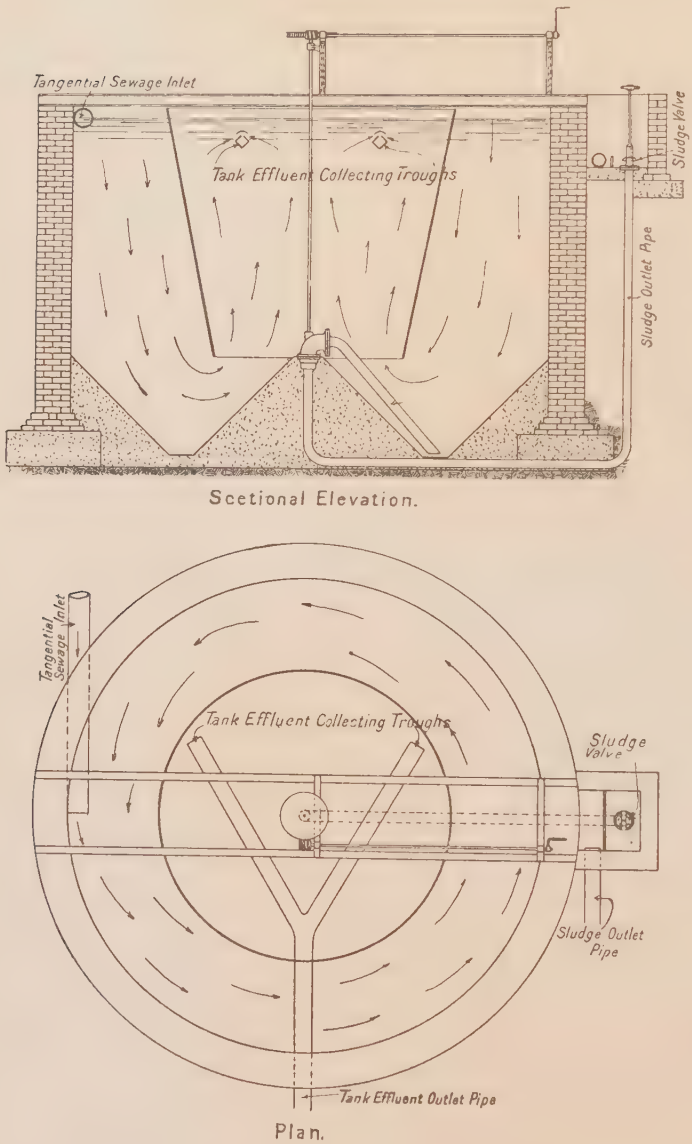


FIG. 3.—*See* Candy Settling Tank (p. 68).

In this connection it should be stated that the experience of many engineers is in favour of dealing with well sedimented sewage upon bacteria beds, with the special object of avoiding septic conditions altogether, and of completing the purification of the sewage whilst it is as "fresh" as possible, thus contributing largely to the avoidance of possible nuisance from smell. In the case of many classes of sewage, the idea of the septic tank is falling into disfavour as experience has shown that it is not necessary, and indeed is sometimes positively harmful, that sewage should be made putrid (as the name implies) preparatory to the second or oxidising stage of the purification process.

Tanks of the Dortmund type (*see* "DORTMUND TANKS") have been tried for the preliminary preparation of the sewage, but trouble commonly arises from the deposits of sludge and bacterial growths on the inner walls, which deposits, as they decompose, are carried away in the effluent. If kept free from this objection this type of tank gives better settlement as the sewage enters and leaves the

tank on the upward flow principle, but it is not probable that the degree of digestion of the sludge is equal to that which takes place in the ordinary rectangular form of tank.

Recent experience in the use of septic tanks, both open and closed, goes to show that, unless there is some special local reason to the contrary, no real advantage is gained, either as regards the digestion of sludge or quality of the tank liquor, by constructing a closed or practically air-tight tank. The roofing over of the tank, however, has the effect of keeping the gases given off by the septic sewage under better control, so as to limit the nuisance from smell, as experienced at Gosport, Carshalton, Guildford, and Ilford. A light covering, such as of galvanised iron, is sometimes useful, as it prevents disturbance of the surface scum by wind and rain, and hides the unsightly appearance of a septic tank in use.

The inlets and outlets to and from open septic tanks should, of course, be submerged as in the case of the covered tank, and may be arranged by passing the sewage in and out of the tank over a weir behind a scum board to avoid disturbance of the general body of the sewage or the surface of the scum.

The liquor from a closed tank sprayed upon filters or distributed on land is much more likely to cause nuisance than a similar effluent from an open tank, but where the sewage is prepared in plain sedimentation tanks and passed through the final stage of purification whilst fresh, there is but little risk of nuisance under proper management with sewages of average quality. "Contact beds" in good working order are less likely to cause nuisance from smell than "percolating beds" on which the sewage is sprayed, and, from the nuisance point of view, the less the sewage is agitated the better.

The gas generated in closed septic tanks consists of about 73 % marsh gas which is inodorous, 6 °/$_{\circ}$ of carbon dioxide, 5 °/$_{\circ}$ hydrogen, and a quantity of nitrogen. It burns freely, and has been estimated to possess from one-half to two-thirds the value of coal gas of 16 candle power. The gas is not luminous of itself, but becomes so when burnt with an incandescent mantle. Dangerous explosions have occurred with the gas, and care in handling it or bringing a light to the septic tank should be exercised.

The liquor from a septic tank often shows a marked increase in the total solids in solution or fine suspension, and several expedients have been tried to mechanically strain out the latter. Filtering materials of varying grade and quality have been placed at the outlet end of the tank in such a manner that the liquor should pass through and be subjected to rough filtration. Experiments of this sort have been tried at Leeds, Guildford, Chester, and Ilford, but the materials rapidly choke, and in one way or another become ineffective. At Salford the precipitation tank liquor is forced through "roughing filters," under a head of 5 ft. 6 in., and by this means 75 °/$_{\circ}$ of the suspended matter is removed before passing the water on to the percolating beds. The roughing filters are 3 ft. deep and consist of coarse gravel ½ in. to 1½ in. diameter. The liquor is passed through at the high rate of 4,000 gallons per square yard per day.

Before passing to the low-level percolating filters at Friern Barnet the precipitated sewage is given 2 hours' treatment in roughing filters, or contact beds containing medium-sized clinker, and by this means a good deal of the suspended matter is removed. At Birmingham "Dortmund" tanks are placed between the septic tanks and the filters. The tank liquor contains over 19 parts per 100,000 of suspended matter and about 75 °/$_{\circ}$ of this is removed by the Dortmund tanks.

For average domestic sewages which have been roughly screened and subjected to simple sedimentation, a "Preliminary Preparation Tank" of the design shown in Fig. 2 (p. 400) will be found advantageous for the elimination of a large proportion of the suspended solids. At the inlet end the heavier portion of the solids still remaining in the sewage is held back in

a compartment containing iron baffle plates, whilst further dissolution and subsidence of fine suspended matter takes place in storage compartments behind submerged cross walls preparatory to an aërobic treatment in contact with well vitrified clinker, under which latter the partially clarified sewage enters by means of an aërating floor and passes upwards and over a sill to the adjoining compartment or away to the tank effluent channel off which the supplies to the percolating beds are taken. The sludge, or deposit, from all the compartments of this tank is readily removed by opening the outlet valves provided for each separate chamber, such outlets being all connected up with a single sludge outlet drain which discharges under the hydrostatic head or pressure afforded by the sewage in the full tank, thus reducing labour to a minimum. The effluent from the tank is well prepared for passing through "distributors" upon aërobic trickling-filters without causing trouble from clogging, or it may with advantage be satisfactorily dealt with direct upon land.

Another means of reducing the suspended solids has been suggested consisting of the addition of a few grains of lime per gallon to the septic tank liquor; this also has the effect of reducing the offensive character of the liquor.

Preliminary Preparation of Sewage by Chemical Precipitation.—At one time chemical precipitation was looked upon as a leading method of purification, but, as a result of recent developments in sewage purification, it must now be regarded as an auxiliary means of preliminary preparation of certain classes of sewage, mainly those containing "trade wastes," for the purpose of rendering the same suitable for subsequent distribution upon oxidising beds. The chemical precipitation of domestic sewage with a 2 hours' rest may produce a tank liquor containing an average of 2 or 3 parts per 100,000 of suspended matter as compared with, say, 4 or 5 parts per 100,000 in the case of a continuous flow tank working at an 8-hour rate. Of the many precipitants employed in different places, lime and alumino-ferric are very largely used either alone or together, according to the nature of the sewage. When used together some 4 or 5 grains per gallon of lime are mixed with the sewage as compared with from 2 to 4 grains of alumino-ferric, but the best proportions to be adopted necessarily vary with the nature of the sewage, and are dictated by experience. These precipitants are used at Ealing, Willesden, Dorking, York, Friern Barnet, and other places. Lime is also used in conjunction with copperas (ferrous

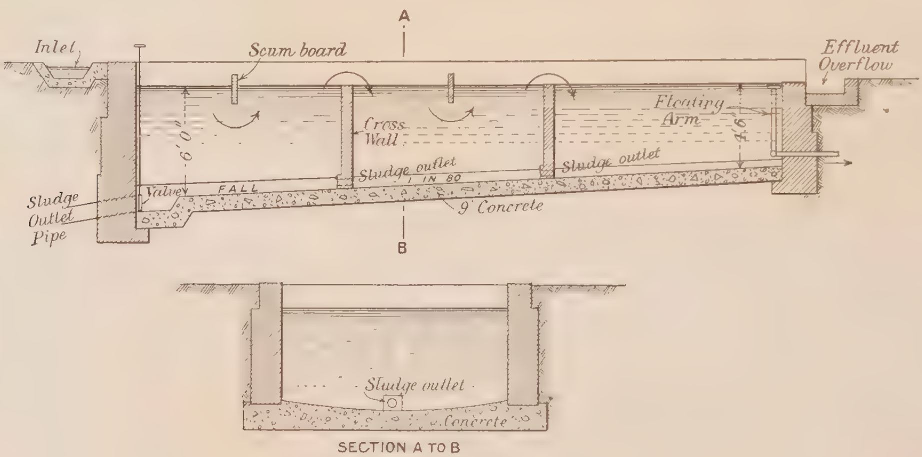


Fig. 4.—*See* Precipitating or Settling Tank (p. 335).

sulphate), and at Kingston alumino-ferric is used with blood, charcoal, and clay (A. B. C. process). Other precipitants are Hanson's sulphurous powder, ferric sulphate, aluminum sulphate, ferrozone, and sulphuric acid, between 4 and 5 grains of the latter being used at Rochdale, where the sewage is strong, with about 7 grains of alumino-ferric. The average cost of precipitant in five towns where about 6 grains per gallon of alumino-ferric alone is used is about 15*s.* per million gallons of average daily flow, as compared with 11*s.* per million gallons in five other towns using 5 grains of lime and 3 grains alumino-ferric on the average. From 80 to 85 % of the suspended matter in the crude sewage is precipitated by the use of from 6 to 7 grains per gallon of alumino-ferric, but it should be remembered that the greater the amount of suspended solids in the crude sewage the easier it is to secure a good percentage of reduction. At Kingston, above referred to, no less than 95 % of suspended matter is thrown down, showing the A. B. C. method to be an efficient means of precipitation, but the quantity of sludge produced is large. The lime process does not yield a very satisfactory effluent, but is useful to neutralise an acid sewage. There is considerable difficulty in accurately adjusting the quantity of lime to the sewage, usually resulting in much lime being left in solution (*see* "Lime Process"). The proper precipitant to use in any individual case depends upon the chemical composition of the sewage; special sewages require special treatment—for example, at Bradford and Rochdale sulphuric acid is used to neutralise the alkali in the wool-scouring refuse, whilst large quantities of lime are added to the Burton-on-Trent sewage on account of the large proportion of brewery waste it contains.

The most effective method of adding chemical precipitants is in the form of a solution and well agitating the sewage by mechanical means. At small works precipitants such as ferrozone and alumino-ferric is often added in the form of a solid block placed in the main sewage carrier and allowed to dissolve by the flow of sewage.

The clarification of sewage in tanks with the aid of chemical precipitants may be expected to cost about £3 per million gallons of dry weather flow of sewage, including labour, chemicals, and loan charges, as against about one-half that amount for simple continuous flow settlement or in open septic tanks. But in this connection it must be remembered that chemically precipitated sewage contains less suspended and colloidal matter than sewage which has been settled without chemicals or through a septic tank, so that a larger quantity can be treated per cubic yard capacity of oxidising filters and a finer grade of material may be used.

Septic tank liquors frequently contain more colloidal matter than their corresponding sewages, the effect of which is to increase the clogging effect upon fine-grained filters. For very strong sewages, therefore, a preliminary preparation by chemical precipitation may be more advantageous than by septic tank treatment, especially in cases where the sewage contains tannery or brewery wastes. A large part of the colloidal matters are thrown down as sludge by chemical precipitation, and sludge so produced is commonly less costly per ton to press than that from septic tanks, but the volume produced is larger.

Suitable preliminary treatment of any sewage must be regarded as a most important part of the process of purification, as upon this largely depends the degree of success, or otherwise, of the second or oxidising stage to which the tank liquor is subjected, and the most economical and advantageous local means of dealing with the sludge will doubtless always prove a leading factor in the choice of a system of sewage disposal.

Having dealt in the preceding pages with the various methods of "preliminary preparation" of sewage and with the question of the disposal of sludge resulting from such treatment, the remaining problem to be considered is principally that of the various methods of thoroughly oxidising the organic matters

contained, in solution and in suspension, in the partially clarified effluents from the preliminary preparation tanks. This second stage of the process is carried out upon artificially prepared sewage filters or upon land. Filters, as now constructed, are broadly speaking of two classes, viz.: "contact beds" and "percolating filters."

Contact Beds.—These are simply tanks filled with some durable form of filtering material, in which the sewage is held up for a definite period of time in "contact" with the medium, after which it is quickly discharged and the bed allowed to stand empty for a fixed period in order that it may aërate and recuperate in readiness for the next filling. By this method there is, therefore, a continual succession of periods of "contact," or work alternating with periods of "rest" or recuperation. With percolating filters the sewage is permitted to regularly percolate through the bed, and is not held up as in the preceding case. Both types of filter are capable of oxidising organic matter in solution in sewage when working under proper conditions, but the relative merits of each require careful consideration before adoption in any particular case. Generally speaking at the present time the "percolation bed" is in the greatest favour, and is capable of treating nearly double the quantity of tank liquor per cubic yard of medium, as compared with the contact bed. Exactly what takes place in the course of purification within the contact bed is not fully understood, and comparatively little is known as to the kinds of bacteria essential to purification, but it is generally believed that bacteriological activity during the resting or aërating period of the bed is an important and indispensable part of the cycle of work. Some purification is also doubtless effected by worms, infusoria of many kinds, and other low forms of life in addition to bacteria.

Contact beds in several instances were first constructed by simply excavating for the bed and refilling with burnt ballast or other conveniently accessible material as a medium, but there are many objections to this plan. Such beds can seldom either be made or kept water-tight, as rats and moles burrow through the sides and bottom, and unpurified sewage leaks from one bed to the other and finds underground courses and outlets. Trouble of this description has been experienced at Sutton, Oswestry, Heywood, and Halton, whilst on the other hand somewhat more satisfactory results have been experienced from a similar mode of construction in heavy clay soils at Burnley and Oldham. The materials within contact beds should be of a permanent character, not easily pulverised or reducible by sinkage or crushing, or the beds rapidly lose capacity and choke, owing largely to insufficient aëration through the body of the bed for the proper development of bacterial life.

In the construction of the biological contact bed the object is to deal with a foul liquid containing but little free oxygen and large quantities of oxidisable organic matter, the oxidation of which is effected through the agency of living organisms requiring an adequate supply of air. The growth of such organisms coats the filtering medium with a slimy jelly consisting of masses of bacteria and zoogloea. Dr. Fowler has pointed out that if this material is placed in a tube containing air and connected with a manometer (*see* "Manometer") the jelly will rapidly absorb all the oxygen and produce carbon dioxide. This action will sometimes produce a vacuum of several inches of mercury, showing that there is little need to force air into a bed, as has been experimentally tried, as the natural interchange of gases thus taking place is sufficient for adequate aëration.

The new contact bed, of course, contains no such organisms, but the sewage itself carries the necessary bacterial life for its purification, and as this develops, the bed is gradually brought into a state of high efficiency, as shown by the presence in the effluent of increasing proportions of nitric acid. After a sufficient contact the emptying of the bed from below has the effect of drawing a

further supply of air into the interstices of the material at each period of rest. The "resting" of the bed, say for 12 hours out of each 24, is one of the distinguishing features of the mode of working a bacterial bed as compared with the earlier sewage and waterworks filters, the action of which was formerly regarded as wholly mechanical. If the bed be worked at a high speed without sufficient daily rest the effluent may remain good, but the capacity of the bed will be reduced by the rapidly increasing bacterial growths, which cause the bed to become too spongy and prevent its liquid contents from draining away. Thus, a decrease of capacity is accompanied by an increase in efficiency, just as is also experienced in the use of a waterworks sand filter as the gelatinous growths develop on the surface of the sand. If, however, the growths within the contact bed become so great as to interfere with the practical utility of the bed, these will be rapidly consumed by giving the bed a long rest of from 1 to 2 weeks, at the end of which its capacity will be greatly increased. A longer period of rest than this is not advisable, as the slimy growth or bacterial jelly coated upon the material of the bed tends to dry up and so to inhibit the activity of the micro-organisms. In winter, too, their action is diminished when deprived of the heat of the sewage during prolonged periods of rest. When once a bed is matured it is better, therefore, to relieve the work upon it by reducing the number of fillings per day than to put it out of use altogether when not required for the volume of sewage to be dealt with.

The period of "contact" in a bed obviously has an important bearing on the area of beds required for any given volume. The ordinary 8-hour cycle of operations allows 1 hour to fill, 2 hours resting full in contact, 1 hour to empty, and 4 hours resting empty for aëration. Experience shows, however, that, although this round of operations may be regarded as a fairly average condition of working, it admits of considerable modification in individual circumstances. The age of the beds and the strength of the sewage treated are important factors of the case. The present tendency is to shorten the period of contact, and it appears clear that the period of rest is of greater importance than that of contact. The bed, too, should be filled and emptied as quickly as possible so that all parts from top to bottom may be uniformly aërated throughout, care being taken, of course, that no disturbance of the materials in the bed should occur. On the whole about half an hour for filling, 1 hour's contact, with half an hour or a little more for emptying, may be taken as a satisfactory cycle, subject of course to modifications to suit special sewages under treatment. Assuming a maximum of 6 hours' rest this will allow three fillings a day, or if a maximum of 4 hours' rest only, four fillings in the 24 hours.

The length of time required for a new bed to mature varies greatly and is found to depend on the nature and strength of the sewage and on the temperature prevailing or seasons of the year. In some cases it has been barely more than a matter of days, in others it has taken about three weeks, whilst in some instances as many months may be occupied in the development of the necessary growths. Provided adequate precautions are taken, as by the use of detritus chambers, to exclude inorganic substances such as road grit, &c., a bacteria bed when once started, if intelligently worked, should continue to improve and deal with increasing quantities of sewage after the initial reduction of liquid capacity inseparable from a new bed has been passed.

The question of the permanent liquid capacity of contact beds is one of considerable importance as affecting the practical working of the system as well as the initial outlay in area of beds and subsequent working expenses in renewal of the material. The first experiences of loss of capacity proved to be very largely due to the use of unsuitable and improperly graded materials and to the lack of appreciation of the distinction between loss which occurs whilst the bed is getting into

condition and that which can be regarded as a genuine "sludging up" of its interstices. Later experience shows that a regular working capacity of about 33 % of the cubic contents of the bed can be relied upon in the case of "primary contact" beds—a proportion which has been adopted by the Local Government Board as a requirement in the design of new schemes. The average capacity of a "secondary" bed receiving effluent from a corresponding primary bed is about 40 % of the original contents of the empty tank. Upon the first filling of a new bed its liquid capacity may be well over 50 % of the total cubic contents, but this proportion will gradually decline as the bed comes into working condition, and periodic resting is always necessary to keep the bacterial growths within proper limits. A marked increase of capacity is noticeable after the bed has rested for several days owing to more complete drainage and to the removal by oxidation of much of the organic matter accumulated within the bed. There are many causes which contribute to the loss of capacity in contact beds, some of which may be avoided whilst others cannot. Such loss is due principally to the disintegration and consolidation of the material within the bed, insufficient drainage and aëration, the excessive growth of the bacterial jelly and other low forms of life due largely to overwork and want of aëration, to the excessive volume of tank liquor passed on to the bed and the relatively large amount of suspended matter contained in such liquid, and to the deposition of colloidal matters tending to choke the pores of the filtering material. Insoluble matters may be largely retained on the surface of the bed by using a layer of finer material on the top, the upper portion of which may be skimmed off from time to time as necessary, and the surface periodically loosened by means of a fork.

Some latitude is permissible in regard to the depth to which contact beds should be constructed, but from past experience it appears that a depth of from 4 ft. to 5 ft. is the most generally suitable. A depth of 6 ft. may be regarded as a maximum, and 2 ft. 6 in. as a minimum. A good deal, however, will depend on the fall available in any given case and the relative cost and areas required for shallow and deep beds respectively. Generally speaking, the depth of a bed makes little or no difference in its efficiency per cubic yard of filtering material, but at Exeter, it is interesting to note, nitrification was found to be most active in the body of the filter rather than at the top or bottom, and the greatest purification took place at the depth of 3 ft. down.

Materials for Contact Beds.—In selecting and placing materials in the contact bed it must be remembered that the object is to expose a maximum surface alternately to the sewage and to the air, so that there may be ample areas over which the bacterial growths may take place, and with which the sewage and air alternately may come in contact. The material should be hard and tough and admit of the sewage and air alternately filling all its interstices. It should be strong enough to resist crushing through superincumbent weight. If the material is too much honeycombed and in large pieces, there may be a tendency to retain stale sewage in its crevices, and to reduce the capacity of the bed by holding back a large amount of liquid by capillary attraction. The material should be well screened free from dust and fine stuff, but it is not necessary to keep a strictly uniform size or grade throughout the body of the bed. A variation in size from 1 in. to 3 in. will effect considerable saving in the expense of filling the bed which would otherwise be entailed by two great a refinement in the grading. The drains or aërating tiles on the floor of the bed should be covered with larger-sized material, and the top of the bed overlaid with a 6 in. layer of finer grade, with the object of keeping as much as possible of the suspended matter in the sewage upon the surface of the bed. There is no necessity of forming the bed in layers of different-sized materials; uniformity throughout gives the best results.

The actual material selected in any given

case will naturally depend very largely upon local conditions and facilities for obtaining a suitable medium at the lowest cost. Amongst those which have been successfully employed are good hard vitreous clinker, broken brick rubble, granite, flints, broken "saggers" from the potteries, hard coal, and coke. Slags from iron works can only be used with great caution, as they may be liable to disintegrate under the action of septic sewage, but the vitreous slags from cold blast furnaces have often been found suitable. Carbonate of lime is soluble in the effluent from septic tanks, and any material into which this enters largely will be liable to disintegration. The material used, therefore, should not effervesce under hydrochloric acid; it should be clean when put into the beds, and be washed if necessary. Refuse destructor clinker is often used where this material is produced at or near the site of the bacteria beds, but only the harder and more vitrified portions should be employed. All fine friable dust and small material should be rejected.

Grade of Material.—The decision as to the grade of material to be used should depend largely upon the amount of suspended matter in the tank liquor to be treated, but there is no advantage in using material much over 3 in. grade. Large material does not necessarily prevent, but defers, choking. By its use a considerable part of the sewage is not brought sufficiently into contact with the surfaces carrying bacterial growths to insure the requisite purification, owing to the large interstices between the material. With a well precipitated tank liquor where a good hard well vitrified clinker is used, the gauge may be from $1\frac{1}{2}$ in. to $\frac{3}{4}$ in. for primary beds, and $\frac{3}{4}$ in. to $\frac{1}{4}$ in. for secondary beds—a layer of coarse material, 2 in. to 3 in. gauge, being placed over the aërating floor tiles to assist drainage and ventilation of the bed. Coke is not so good a medium as good hard clinker, as it is apt to disintegrate and sometimes to float in the liquid. The "saggers" from the potteries should make very good material, and in that locality can be delivered in the rough state for about 2*s*. per ton, or, including crushing, screening, and placing in the beds, between 4*s*. and 5*s*. per cubic yard. The weight of a cubic yard is about 18 cwts.

Distribution over Contact Beds.—For the distribution of sewage over contact beds, the elaborate troughing of iron, zinc, wood, &c., complicated with notchings, holes, and adjusting screws, has now mostly been abandoned, and simpler methods followed. It may be accepted that every detail of construction connected with works for the purification of sewage should be of the simplest possible description so as to work with the minimum of attention, to avoid choking by suspended matters in the sewage, and generally getting out of order. In the case of the Manchester contact beds, the sewage is admitted from the supply channel into a shallow basin within the bed, and then passes over a semi-circular weir on to the material of the bed, in which is formed a series of radiating channels or grips, into which is placed finer grade material to keep the grosser solids at the surface, and as the porous surface of these channels becomes choked, the sewage is gradually carried further forward before passing down into the bed. The channels are turned over from time to time as necessary to vary their position. This method has the important advantage of being exceedingly simple. In lieu of the simple grips, half-pipe stoneware channels are sometimes used, but possess no real advantages over the first-named method, except, perhaps, the placing of a few lengths to lead off from the outlet of the feed-siphon valve. In either case the surface of the beds may be practically at the same level as that of the sewage in the septic tanks, unless fall is required for aëration, for long storage channels, a dosing tank, or for other reasons.

For a full bacterial treatment, and a good non-putrefactive effluent, double contact is necessary for most sewages. That is to say, an upper or first contact for the retention and digestion of the grosser impurities in the tank effluent must be followed by lower or second contact beds. These are respectively

described as "coarse" and "fine" beds, according to the grade of material used, and as a rough approximation it may be taken that the first contact will remove about 50 % of the dissolved impurity, and that the second contact disposes of some 50 % of the impurity still remaining in the effluent. If single contact only is given the effluent will require further treatment on good pasture land as in the case of the Beaumont Leys Farm at Leicester. In some cases a good non-putrefactive effluent may be got by subjecting one-half of the sewage to double contact and the remainder to single contact only, and then mixing the effluents so obtained, thus securing what may be regarded as one-and-a-half contact. The "secondary" beds in such a case would be made proportionately smaller and pass the sewage at a more rapid rate, but this reduction in area is not recognised by the rules of the Local Government Board.

Automatic gear for charging and emptying contact beds is useful in small works, where labour is limited, but cannot be left long unattended, and an inspection at least once a day is needed. All apparatus of the kind, however well made, is liable to get out of order and so completely derange the working of the purification system; neither can such devices adapt themselves to the variations of strength and flow of the sewage. A bacterial system must be worked with intelligence and variation of control according to the fluctuations of temperature and quantity and strength of liquid to be treated. Manual labour alone can watch these variations, and so learn by experience how to secure the most favourable result. On large works, where labour is always available, manual control is undoubtedly the best.

A very large variety of apparatus has been introduced for feeding and emptying bacteria beds and for various other purposes, full details of which will be found in the catalogues of the principal makers.

The length of time a contact bed can be worked before it becomes necessary to take out the materials, wash, screen, or renew the same, depends on the nature and grade of such materials, the amount of suspended matter in the tank liquor treated, and other factors. Such "washing" may, however, be necessary every 4 or 5 years in primary beds and every 8 or 10 years in secondary beds, but the true period in any given case depends entirely upon the conditions under which the beds are worked. In some instances it may be cheaper to renew the material entirely if a new supply is readily obtainable, but more often it proves economical to "wash" the old material and make up with new. The cost of removing from beds, wheeling, screening, washing by machinery, and replacing and making up loss with new material commonly varies from 1*s.* to about 2*s.* 3*d.* per cubic yard, as compared with similar work with hand washing costing from 1*s.* 6*d.* to 2*s.* 7*d.* per cubic yard.

The deposition of colloidal matter greatly reduces the capacity of filters in some cases, and the best means of dealing with this difficulty is one of considerable importance, but has not hitherto been fully investigated, though increased attention has been directed to the subject of recent years.

Percolating Beds for the final oxidation of sewage liquor from septic or precipitation tanks are of more recent development than contact beds, and, at present, appear to be growing in favour. The essential features of the percolating system as distinguished from treatment by "contact" are that the liquid is not held up in a water-tight chamber in stationary contact with the clinker or other medium used, but is applied to the bed so as to gradually percolate or trickle through, passing *en route* over the surfaces of the medium which rapidly become coated with bacterial growths. These latter act upon the sewage and bring about its oxidation. The percolating bed is usually made deeper than the contact bed, and special means should be taken to insure regular and thorough aëration of the whole of the filtering medium by means of a hollow or aërating floor with perforated side walls. The percolating bed works continuously, with the exception of short regular intervals for aëration, and it is capable of treating nearly double the

quantity of sewage per cubic yard of bed capacity as compared with the "contact" system. The sewage is sprinkled, in a more or less rain-like fashion, by means of "distributors" (*see* "DISTRIBUTORS, FOR SEWAGE"), and an important point is to secure uniformity of distribution and a regulation of the quantity passing on to the bed. The percolating bed effluent will be found to contain more suspended matter than that from the contact filter and some means will generally be needed to remove the larger portion of this. Its removal from the body of the filter in this way is advantageous, as, in the case of the contact system, it accumulates within the bed and in time chokes the pores of the medium, which must then be removed and washed.

The depth of percolating beds may usefully range from 3 ft. to 5 ft. in the case of fine grade materials, and from 5 ft. to 10 ft. with medium or course grade material. The extent of the purification depends largely upon the length of time the liquid occupies in passing through the bed. With proper aëration and distribution the deeper the bed the better should the effluent be, but each cubic yard of coarse material performs about the same amount of work of purification whether displayed as a deep or as a shallow filter. In the case of fine grade material experience is somewhat in favour of using a given quantity of medium as a shallow filter, as suspended and colloidal matters tend to retard proper aëration, and it has been found that by far the greater part of the purification is performed in the top 3 ft. of depth of the filter and relatively little in the lower parts. In any case, however, filters should not be made shallower than about 3 ft., as imperfections of distribution often lead to the sewage finding direct channels or short cuts through the bed and so reach the effluent channel without having been subjected to the necessary bacterial action. This is particularly the case with beds of coarse material, but with a 6 ft. depth or more, any inequalities of distribution are dispersed and neutralised by passage through the deeper stratum of filtering material.

The time occupied by the sewage in passing through even beds of 9ft. and 10ft. depth is usually very short and does not oftentimes exceed about 5 minutes, thus showing that the process of nitrification is a very rapid one. The actual rate of percolation through depends upon the grade of material used, the condition of its surface, whether smooth like gravel or irregular like clinker, and the degree to which the filter has matured with growths of bacteria, &c. The longer the sewage takes to percolate through, the greater the purification to be expected, assuming, of course, the bed is in good working condition. Better results, too, are obtainable from rough surface material like hard vitreous clinker than in the case of smooth surface stone or gravel affording less surface for contact with bacterial growths.

SURFACE CLOGGING OF PERCOLATING BEDS.—Should the surface of a percolating filter become clogged by means of the deposition of suspended or colloidal matters or by pylobolus growth causing ponding of the sewage, the distribution will be unequal, aëration will be imperfect, and, as a result, oxidised nitrogen will disappear from the effluent which will become putrescible. Shallowness in depth in the case of fine and medium grade filters has the advantage of facilitating aëration, and as the proper working of any percolating filter depends on the free passage of air through the bed, the bottom layers should be as open as possible and be carried on an aërating tile or hollow floor. Surface clogging may be remedied by resting the filter and by digging over the surface with a fork and aërating the filtering material.

At some places much trouble is experienced through the development of thick gelatinous fungoid growths during certain parts of the year, mainly in the winter and early spring, upon the surface of the percolating bed. These cause serious "ponding" and deterioration of the effluent. It has been suggested that chemical precipitation liquors favour the growth of these obstructions, but they also occur with septic tank liquor. As a remedial measure, a 20 % solution of caustic soda has

been successfully used on the surface of the bed, and the deposits afterwards washed out in the effluent.

Distribution on Percolating Beds.—The spraying of sewage on percolating filters is more liable to cause nuisance from smell than treatment on contact beds, but this is very largely avoided by completing the process of purification whilst the sewage is "fresh" and so avoiding the unnecessary generation of offensive gases as occurs when the sewage becomes putrid in a septic tank. During the warm months of the year there is often considerable annoyance from flies in and about percolating filters.

The best means of uniformly distributing sewage over the area of the beds is an important and distinguishing feature of the percolating system, to which too much attention cannot be paid as it directly affects the quality of the effluent secured. This subject is specially dealt with under the head of "Distributors" (q.v.).

Percolation bed effluents are generally better aërated than those from contact beds, and are of a more uniform quality. The first part of the discharge from a contact bed is generally less pure than the average discharge. The percolating filter, too, is better able to cope with variations of flow than its contemporary the contact bed, and, per cubic yard of filtering material, satisfactorily treats nearly double the quantity of tank liquor.

Comparative Cost of Percolating and Contact Beds.—The question of the comparative cost of construction, working, and maintenance of percolation and contact beds respectively is one upon which but little information of practical service can be given, as so much depends upon local conditions and requirements. Every case must be decided on its merits after a full consideration of all such local circumstances. It may be stated generally, however, that under ordinary average conditions the comparative total annual cost of completely treating a given quantity of sewage on the contact and percolating systems respectively is about as 5 is to 3, and, unless there are special local reasons to the contrary, treatment by percolation beds is preferable. The expense of full treatment, including working expenses and loan charges for preliminary processes and oxidation of the tank liquor on percolation beds, may be expected to be in the neighbourhood of £4 per million gallons dry weather flow.

Quantity Treated per Cubic Yard of Percolating Bed.—The quantity of liquid which can be satisfactorily treated per cubic yard of capacity of percolating bed depends upon the strength and nature of such liquid, whether it be partially settled, well settled, septic tank liquor, or precipitation tank effluent. The clearer and more free from suspended solids the liquor may be, the greater the quantity purified per cubic yard of filtering material. Crude sewage or roughly settled sewage should not be placed upon contact or percolating beds if trouble from choking is to be deferred or avoided. With well-settled sewage about 100 gallons per cubic yard of filtering material per day can be treated on percolating beds, or about 150 gallons per cubic yard of septic tank liquor on beds of medium grade material. With clear precipitation tank liquor as much as from 300 to 500 gallons per cubic yard per day may be treated according to the strength of the liquid. In any given case it is safest to find by actual trial and experiment with the sewage to be dealt with the maximum work that can be properly got out of a given quantity of filtering medium. The ordinary rates of working are very commonly doubled when the sewage is weak as in times of storm. The past requirements of the Local Government Board have not recognised any superiority of the continuous filter over the contact bed or *vice versâ*, and the cubic bulk of filtrant must be the same in both. The maximum volume to be treated per cubic yard of filtrant on either process is calculated at 168·7 gallons, which provides for three fillings per day upon contact beds, or for continuous or intermittent discharge upon the spray or percolating beds.

Aëration, Oxidation, and Nitrification.—The purification of sewage is not entirely a simple question of oxidation, but is of a more complex and variable nature, and there may yet be many modifications of present methods dictated by further experience in the future. It appears, however, that the final stage of purification should be one of full aëration with nitrification, and that, generally speaking, with the average domestic sewage, the best known method at the present moment for bringing about this result is in the direction of the continuous passage of the tank liquor through something akin to the now well-known "percolating bed." In some cases it is probable that the denitrification changes are equally important with the nitrification change, as, for example, for the effective oxidation of many substances such as cellulose, and further investigation is required in this connection.

Whatever may be the method of purification adopted, the problem resolves itself largely into one of cost. If money were no object a town's sewage might be converted back into a wholesome drinking water, but, from a practical standpoint, purification is carried far enough when taken well within the limits of a standard of safety appertaining to the case in point, and the true solution of this difficult problem is to bring about this result at the irreducible minimum of cost.

Removal of Suspended Matter in Effluents.—When effluents from bacteria beds contain more than about 3 grains per gallon of suspended matter some special means must be taken to secure their removal. This is done by straining, settlement, or filtration. Settlement may be carried out by slow passage of the effluent through rectangular tanks containing a number of baffle plates and submerged divisions, in Dortmund tanks, or by rapid filtration through shallow beds of fine clinker, or through sand. Although a good deal of the suspended matter is of a light flocculent nature and subsides but slowly, a sufficiently clear effluent may usually be obtained by simple settlement in tanks as above, but if a clearer water is required the extra labour of filtration in addition to tank settlement must be incurred.

Treatment of Sewage on Land.—The fifth report of the Royal Commission on Sewage Disposal, dealing, in Part III., with the purification by treatment on land, opens with the statement that "there can be no doubt that, where the soil is suitable and the area of land sufficient, the organic matters in sewage can be thoroughly oxidised by land treatment. This fact is well established, not only by investigations made by earlier Commissions, but also by wide general experience."

Although attention has been largely diverted during recent years towards other modes of treatment, there is no doubt that the practical

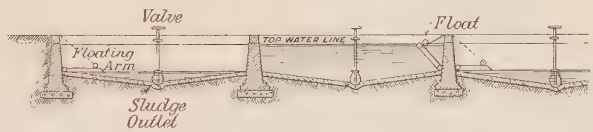


Fig. 5.—Absolute Rest Tank. (*See* p. 4.)

application of modern advances in bacteriological knowledge has given a new and increasing interest in the scientific purification of sewage on the greatest of all bacteria beds, the land. Where a sufficient quantity of suitable land at a reasonable price can be obtained, this still remains the most satisfactory method of disposal, if the conditions are favourable. There have been many failures arising in connection with land treatment, but when the causes are investigated oftentimes it is found that any system similarly abused would afford no greater measure of success. The biological principles involved have been not infrequently entirely disregarded and due attention has not been paid to the capacity of the land in respect of the quantity of sewage that can be satisfactorily dealt with thereon. Another fault commonly met with is that of localising the sewage for long periods upon certain parts only of the total sewageable area, whilst the remaining areas are reserved for cropping and profit-earning purposes. In

other words, the different areas are not sufficiently alternated in periods of work and rest. Former sewage "filters" failed by choking owing to want of appreciation of the necessity for alternating periods of rest, and all land requires like opportunities for the proper digestion of the impurities brought upon it. Suitable cropping, rest, and aëration are aids to purification and especially to the recovery or cleansing of land which has become "sewage sick" through being overworked with sewage.

The old idea of returning the sewage to the land for the sake of the manurial value of the organic matter contained therein has long since proved to be a profitless pursuit, owing mainly to the small quantity of such organic matter in relation to the volume of sewage to be treated.

The land must be regarded as a means of disposing the sewage of the town it serves, and, given proper management, whatever balance there may be on the wrong side of the sewage farm account, it should be looked upon as the cost of performing the important service of disposing of the sewage of that town. Every effort should, of course, be made to keep that cost as low as possible by constant good management and the growing of saleable crops, subject always to the efficient purification of the sewage for which purpose the farm was brought into existence. In this connection it should be remembered that when artificial purification works are once adopted, there will be nothing, in this case, to come back on the income side of the ledger to lighten the cost of working expenses. A midway course is frequently found advantageous from many points of view, viz., to relieve an overworked farm by constructing bacteria beds to treat the dry weather flow or a considerable proportion thereof, and to reserve the land for treatment of storm-water, and, if necessary, the bacteria bed effluent. This course generally results in a greatly improved effluent, and also affords facilities for the necessary agricultural operations to be carried on to greater advantage.

Provided it is properly handled, land will continue to satisfactorily purify sewage for a practically indefinite period, and there are many farms in use to-day which have been satisfactorily operated for purposes of sewage purification for the past 30 years. The sewageble area of land, however, must be increased in proportion to the increase in population served by the farm, in the same way that any other works require to be extended, and adjusted from time to time to the increasing amount of work demanded of them. But it is just at this point that it becomes practically impossible to deal with the sewage of large populated centres by means of land treatment, and also in many instances to extend existing farms serving small and medium-sized towns. Under the Local Government Board Rules, if sewage is treated by "broad-irrigation" on suitable land, after rough screening, the requirements are one acre of land for every 150 of the population at 30 gallons per head, that is, one acre for a volume of 4,500 gallons. The lands required for final treatment of the effluent from bacteria beds is one acre per 30,000 gallons.

Even if "suitable" land could be found, calculating upon the recognised basis, the areas required for most large towns become so considerable as to prohibit the continuance of this mode of disposal, and other means of dealing with larger volumes per unit of area must be sought. It is here that the advantages of the modern bacteria bed become very pronounced, as a means is thus at once afforded of concentrating a relatively large amount of work upon a small area, producing, in fact, what may be regarded as an intensified land process, occupying but a small fraction of the area.

Much careful attention has been given to the question of land treatment by the present Royal Commission on Sewage Disposal, and, in their fifth report, when comparing effluents from land with those from artificial filters, the Commissioners state that "judged by chemical analysis both classes of effluent

possess similar qualities. As regards the eight farms which we have had under observation, the average purification, calculated on the atmospheric oxygen used up, and giving credit for the oxygen contained in the effluent in the form of nitrate, was about 98 %. It would have been rather higher than this if the suspended solids had been eliminated from those effluents which contained them. As regards seven contact bed plants which we have examined, the average purification on the same basis, but eliminating the suspended solids, was 93·4 %. As regards six installations of percolating filters, our analyses show that the average purification, after eliminating the suspended solids, was 99·4 %."

The Commissioners further state that "speaking generally, the effluents which we have examined from artificial filters as at present constructed and used are not equal in purity to effluents from the best land, when treating a comparatively small quantity per acre, as at Nottingham . . . . Our investigations have not shown that there is any essential bacteriological distinction between effluents from land and effluents from artificial filters, though effluents from land usually contain fewer micro-organisms than effluents from the artificial filters which are at present in use."

Quantity of Sewage per Acre of Land.—The question of the quantity of sewage which can be treated on a given area of land depends upon the strength of the sewage, the quality and depth of the soil and subsoil, whether filtration or surface irrigation is followed, the nature of the cropping of the land, the amount of suspended solids in the sewage, and the nature and thoroughness of the work of preliminary preparation of the sewage before passing on to the land. Irrigation without precipitation is inadvisable owing to the rapid choking of the land from the large quantities of solids. Under this system with stiff clay one acre per 25 persons would be required on the average, or one acre per 100 persons on loamy gravel. With intermittent filtration without precipitation on sandy gravel, one acre for every 100 to 300 persons would be needed, whilst with intermittent filtration combined with precipitation the sewage of from 500 to 600 persons could be dealt with per acre of sandy gravel. In the case of broad irrigation preceded by precipitation on clay, one acre for every 200 persons, and one acre for every 400 in the case of loamy gravel should be allowed. Where the liquid passing on to the land is of a specially well-prepared description, such as is obtained by precipitation followed by filtration through bacteria beds or specially constructed filters, one acre for every 2,000 persons should suffice. It should be understood that these figures represent what may be expected under average conditions, but practical experience must guide the engineer in forming his opinion of the sewage-treating capacity of any given site. Very commonly about four-fifths of a surface irrigation farm, and two-thirds of a land filtration farm, is resting, it being assumed that the remaining one-fifth and one-third are sufficient to deal with the sewage, and that the different sections fall in for sewaging purposes in rotation.

In regard to the question as to whether a sewage farm is dangerous to health, the Commissioners in their fifth report state that "no proof has yet been furnished of direct or wide-spread injury to health, in the case of well-managed sewage farms." It is interesting to note here that the report for 1905 on the sewage farm of Berlin contains the following statement:—"We can only repeat here what we have said in previous reports, that the sewage treatment has had no injurious effect upon health." This farm has an area of about 39,000 acres of sandy soil, and a resident population in 1905 of 4,198 persons.

Distribution over Land.—The main sewage-feeding carriers should contour the land at the highest possible elevation, so that every possible part of the area may be brought within "flowing" range. A fall of 1 in 500 to 700 will usually be sufficient for these main carriers, the approximate size of which may be about 18 in. to 2 ft. wide by about 18 in. deep,

varying, of course, according to the quantity of sewage flow. They are commonly constructed of concrete, brickwork, concrete tubing or semi-circular concrete channels, and sometimes of stoneware channels. The latter are rather dangerous for cattle in some situations. Outlet chambers with valves are provided at intervals for taking off branch or supplementary supplies to various parts of the land and for the purpose of feeding secondary distributing carriers. These latter are usually cut in the earth along contour lines at different levels down the slope of land under irrigation. The position of the earthen carriers are varied from time to time according to the areas of land to be irrigated.

Fig. 6.—Sewage Irrigation: Catchwater System.

In distributing sewage over steep ground what is known as the "catchwater" method is employed, in which the earthen carriers are cut at short intervals of level along contour lines, so that as the water flows down the slope it is intercepted, and prevented from flowing off the land to the final outlet carrier before receiving proper treatment.

Fig. 7.—Broad Irrigation: Ridge and Furrow System.

In the case of broad irrigation over flat land with heavy soil, the "ridge and furrow" system of distribution is followed. The ridges are about 33 ft. apart, and the furrows have a slight fall longitudinally. Wet soils may be greatly relieved of excessive moisture by this method.

The preparation of the land for broad irrigation should be as simple and cheap as possible, but the surface should be well trenched and levelled, with, as far as practicable, a uniform easy grade. There should be no irregularities of surface to cause ponding of the sewage and waterlogging of the land. There is no precise line of distinction between one class of land and another, but all kinds of gradations are met with between the extremes of light sandy loam and impervious clay. Hand trenching, deep digging, and steam ploughing are the most effective forms of cultivation.

Cropping. — This is a matter which is largely influenced by local requirements, but almost all ordinary crops may be grown, except when the volume of sewage, as is sometimes the case with broad irrigation, is too large, or the areas available too restricted, cereals cannot be grown, and the crops must be limited to rye-grass, mangold-wurzel, osiers, &c. Sometimes the sewage is passed through beds closely planted with duckweed, American water-weed, anacharis, common reed, flowering rush, &c.; beds of osiers or alder trees are also sometimes used, but the soil is apt to become overcharged with organic impurity through want of rest and aëration, and the market for the cut osiers is now not so good as formerly. Unless there is plenty of land available for sewage-flowing, the crops must not be such as to prohibit the use of the land for sewage purposes upon an emergency, if so required. Rye-grass absorbs a large amount of moisture, but in many districts it is difficult to find a sale for the large quantities grown.

Under-Drainage.—Probably the best class of land for sewage treatment would be one consisting of a surface layer of alluvium upon a subsoil of porous material, such as chalk, gravel, and such like; but even with land of this description it will be necessary to see that means, either natural or artificial, exist for

the regular removal of subsoil water, thus keeping down the level of saturation, and facilitating the penetration of air as deep as possible into the soil. Aëration and drainage is also improved by deep trenching and ploughing, which greatly assist the proper oxidation of the sewage. In putting in under-drains no advantage is gained in laying them deeper than from 3 to 4 ft., as the work of purification is mainly done in the top layers of soil. The main "pick-up" drains will, of course, often need to be placed at a greater depth, for purposes of securing suitable gradients. It is very undesirable to under-drain clay lands at all, as it is found impracticable to prevent such land from cracking, and so permitting untreated sewage to find its way down to the drains. The draining of clay land tends to increase the tendency to crack. Results may, however, be improved by irrigating the lower land by effluents from the upper portions, thus securing a double or treble application. Under-drains are usually laid in parallel lines, from half a chain to one chain apart, and are commonly of 2 in. diameter agricultural butt pipes, 12 in. long. About 660 of such pipes are required per acre if laid one chain apart, exclusive of the larger sized pick-up drains running in a transverse direction. Fine ashes, gravel, or surface soil is often placed around the under-drains, to insure filtration through a certain thickness of material before reaching the drains. Rats and moles should be constantly trapped, as their burrows allow sewage to pass away to the under-drains.

Intermittent Filtration is the system under which land is laid out in level beds, and the sewage applied thereto at regulated intervals filters downwards through the pervious soil and escapes by means of drains, or through a porous bed of gravel. Clay soils are not adapted for land filtration. Upon suitable soils the sewage of about 1,000 persons per acre can be dealt with. The distribution is usually done by ridge and furrows, Fig. 8, so as to secure uniformity of application. The positions of the furrows are altered every winter or early spring, care being taken to avoid placing the same over under-drains. After efficient precipitation in tanks the filtration of the liquor through specially prepared land filtration areas should yield a very satisfactory effluent, especially where the land is allowed proper rest, and frequently dug or ploughed over.

The Selection of a System of Sewage Treatment depends very largely upon local conditions and requirements, such, for example, as the character of the sewage, the price and facilities of obtaining land, and the local materials available for constructing artificial filters. In the fifth report (1908) of the Royal Commission on Sewage Disposal, some observations on the choice

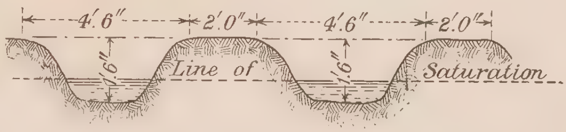


Fig. 8.—Intermittent Filtration: Ridge and Furrow System.

of a method of sewage treatment refer to land treatment in the following terms:—"If a sufficient quantity of good land, to which the sewage can flow by gravitation, can be purchased for about £100 an acre, land treatment would, we think, usually be the cheapest method to adopt. Or, if the case were one in which it was necessary to obtain a high class effluent, it might be cheaper to pay a somewhat higher price for good land, rather than to adopt artificial treatment, because effluents obtained from the treatment of sewage on artificial filters, as usually carried out in practice, are generally distinctly inferior to those obtained by the treatment of sewage on good land, and some addition to the ordinary artificial plant would therefore be required. On good land, a sewage of average strength, from which the major portion of the suspended solids have been eliminated by tank treatment, can be treated at about the rate of 30,000 gallons per acre per day, with the production of a high

class effluent. If the land available were of only medium quality, capable, say, of treating only half this quantity, its use might still be economical, if it could be acquired at about £50 an acre. In cases where only clay land was available it would generally be cheaper and more satisfactory to provide artificial filters." Having regard to the fact that the disposal of sludge is an important factor in all methods of sewage treatment, this aspect of the question necessarily largely influences the final choice of a system. Continuous flow tanks and septic tanks yield less sludge per given volume of sewage than would be derived from chemical precipitation tanks, and the former could, therefore, be most economically adopted under circumstances where it was desirable to limit the output of sludge as far as possible, and the latter where fine grade percolating beds are proposed to be adopted, upon which a tank liquor as free as possible from suspended matter would preferably be used.

The question of the possibility of nuisance from smell also materially affects the final choice of a system, and in this connection contact beds would probably involve less risk of nuisance than percolating filters; but with the former double, and in some cases treble, contact would be required to give the necessary degree of purity. With ordinary domestic fresh sewage there is very little risk of creating nuisance upon percolating beds. W. H. M.

Reference.—For further information on "Sewage Disposal," see articles :—

A.B.C. Process
"Absolute-rest" Tank
Aërobic and Anaërobic Treatment of Sewage
Alumina and Lime
Amine's Process
Analysis of Sewage
Bacteriology
Boston Sewage Purification
Candy Settling Tank
Colloidal Matters in Sewage
Conder's Sulphate of Iron Process
Cosham Tank
Cultivation Tank
Dale's Muriate of Iron Process
Distributors
Dortmund Tank
Dosing Tank
Dry-weather Flow
Ducat Filter
Dundrum Tank
Effluents
Electrolysis
Ferozone
Ferrometer
Fish Life in Streams
Hermite Process
Howatson Process
Hydrolytic Tank
International Process
Ive's Tank
Liernur System
Lime and Sulphate of Iron
Lime Process
Local Government Board Requirements
London Main Drainage
Manchester Experts Report
Manchester Sewage Disposal
Micro-organisms in Sewage
Nitrification
Ohio Water Supply and Sewage Disposal
Oxidation of Sewage
Oxynite
Polarite
Precipitating or Settling Tanks
Richmond Sewage Disposal
Rivers Board and Central Authority
Rivers, Purification of
Royal Commissions on Sewage Disposal
Slate Beds
Sludge
Spence's Alumino-ferric
Standards of Purity (*see* Effluents)
Storm Water
Trade Effluents
Wanklyn and Cooper's System

Sewage Disposal, Royal Commission on.—The last Royal Commission on Sewage Disposal was appointed on 7th May, 1898. The immediate occasion of the appointment of the Commission was the unsatisfactory position of the question of sewage disposal, and the possibilities opened up by the bacterial processes of treatment which had recently been introduced. The Commissioners themselves observe that in many parts of England the pollution of rivers went on unchecked, notwithstanding the fact that the Rivers Pollution Act had been on the Statute-book for over a quarter of a century. This state of affairs was partly attributable to a deadlock between the Local Government Board and the local authorities, due to the practice of the former of declining to sanction any loan for sewerage or sewage disposal unless provision were made for passing the sewage over land, and the impossibility in many cases of obtaining land of suitable quality.

The Commissioners have examined a very large number of witnesses, inspected many sewage works throughout the country, and carried out, through their own officers, some important experiments and investigations. They have already issued six reports, comprising in all twenty-four volumes.

The first, or "Interim," report appeared

on 12th July, 1901. In it the Commissioners review the work of the previous Sewage Commissions which were appointed between 1857 and 1884, and state certain conclusions of their own. They recognise that peat and stiff clay are generally unsuitable for the purification of sewage, and that in certain cases land treatment is impracticable. They express themselves also as satisfied that it is practicable by so-called "artificial" processes to produce good effluents from sewage, either alone or mixed with certain trade refuse; and they think that the Local Government Board would be justified in modifying their rule calling for land treatment.

The second report (issued on 7th July, 1902) consisted of a series of reports by the officers of the Commission, relating almost exclusively to the influence of bacterial processes on disease germs.

The Commissioners' third report (2nd March, 1903) deals chiefly with trade effluents, and with the conflicting state of the law relating thereto. The Commissioners find that sewage containing these effluents is generally more difficult to purify than ordinary sewage, but that it is practicable, in the great majority of cases, to purify mixtures of sewage and trade effluents if the manufacturers adopt reasonable means for removing the solids, equalising the discharge, and where necessary neutralising the trade effluent. They strongly recommend the creation of a Central Authority to determine differences arising between manufacturers and local authorities, and of Rivers Boards to deal with questions of pollution and other matters affecting the rivers within their respective areas.

The fourth report (made 28th December, 1903) deals exclusively with the pollution of tidal waters, with special reference to the contamination of shellfish. The Commissioners reject as too sweeping the suggestion that all sewage should be purified before being discharged into tidal waters, but they strongly recommend that such waters be placed under the jurisdiction of some competent authority having power to prevent the taking of shellfish from any position liable to dangerous contamination.

The fourth report was accompanied by a series of five volumes containing reports by the officers of the Commission on the general, chemical, bacteriological and engineering aspects of the land treatment of sewage. The reporters found that the effluents from land possess a bacterial flora characteristic of sewage, and are not, from a bacteriological point of view, in a proper condition for discharge into drinking water streams. Generally speaking, however, those effluents did not exercise any marked prejudicial effect on the streams into which they were discharged.

The fifth report (7th August, 1908) is separated from the fourth by an interval of nearly five years. The volume of evidence which accompanies it contains a comprehensive record of the methods employed and the results obtained at most of the important sewage works throughout the country, as well as of the opinions held by those engaged in the treatment of sewage on many disputed points. To assist them in forming their conclusions the Commissioners also carried out a series of experiments of their own. The following are the more important of the conclusions arrived at:—

There is no essential distinction between the effluents from land and those from artificially constructed filters: the effluents from the best land are of a higher class than those from artificial filters as at present used and constructed; but the effluents from soils which are not well adapted for the purification of sewage may often be very impure.

Assuming that really suitable land can be purchased at £100 per acre, land treatment of sewage is probably cheaper than artificial treatment.

Chemical precipitation is to be preferred to simple sedimentation or septic treatment where the sewage is very strong or contains much colloidal matter, or where brewery or

tannery waste is present in such quantities as to involve the risk of nuisance.

The effluents from trickling filters were found to be more uniform and better aërated than those from contact beds, and it was considered that a cubic yard of filtering material arranged as a trickling filter would generally treat about twice as much tank liquor as a cubic yard of material in a contact bed.

The risk of nuisance from smell is greater with trickling filters than with contact beds, and there is also with the former a nuisance from flies, especially if the filters are constructed of coarse material.

The separate system of sewerage is considered suitable only for villages, country districts and suburban areas, where there is little traffic.

In the treatment of storm water, the Commissioners recommend some radical departures from the practice which had previously been enjoined by the Local Government Board. Storm water, flowing at too great a rate to be passed through the ordinary tanks and filters, should be subjected to settlement in special tanks, and may then usually be discharged without filtration. The provision of special storm water filters is condemned.

They are strongly of opinion that questions as to the amount of sewage which should be filtered in storm times, and also as to any standards which may be adopted for effluents, should depend on local circumstances. They deprecate the adoption of standards of bacteriological purity, and of sterilisation processes, both on the score of cost, and because of the false sense of security which they would be apt to engender.

Having dealt with the question of the purification of sewage by local authorities, the Commissioners go on to investigate that of the disposal of trade effluents apart from sewage. Their sixth report (dated 9th February, 1909) is concerned with the disposal of the liquid refuse from distilleries. Serious complaints had been made of the pollution by this refuse of certain rivers in the north of Scotland, and of the consequent injury to the salmon fisheries. The evil had been growing rapidly for many years, and no method was known whereby the refuse in question could be effectually purified at any reasonable cost. As the result of experiments of their own, the Commissioners found that a satisfactory effluent could be obtained by dilution, treatment with lime, and filtration through trickling filters. In the case of distilleries situated in towns, they recommend the admission of the refuse to the sewers.

The investigations still in progress relate to the disposal of other trade effluents, the question of standards and tests, and that of the manurial value of sewage sludge.

The keynote of the Commissioners' reports is that any statutory provisions must be elastic, with an ultimate appeal to a properly equipped Central Department armed with full powers. Not the least important outcome of their work is the effective demonstration which it affords of the extreme variations in the composition of the sewage of different towns and the diversity of the conditions under which it is discharged, the failure to recognise which has lain at the root of the difficulties which have been experienced in the past. Not only have they exposed the ineffectiveness of many of the particular regulations which have hitherto been insisted upon, but they have shown the impossibility of governing the future disposal of sewage by means of any system of arbitrary rules. To quote their own words:—"Since the date of our appointment considerable developments have taken place in regard to the disposal of sewage, and there is every reason to think that further changes will occur in the future." A. J. M.

Sewage Disposal (Reports on).—During recent years much original experimental work has been carried on by those responsible for the design and working of sewage purification works. Such reports embody practical results

and opinions in respect of the experience thus derived and form a useful mass of literature which has contributed largely to the building up of a more widely disseminated knowledge of bacterial methods of sewage purification. Amongst others may be enumerated the following examples:—

1. Expert's Report on the Treatment of Manchester Sewage (1899).
2. Report on Sewage Disposal, City of Leeds (1900).
3. Sewage Disposal at Hanley (1904).
4. Report on Sewage Disposal, Borough of Leicester (1900).
5. Annual Reports of Rivers Department, City of Manchester.
6. Reports on Sewage Disposal, London County Council.
7. Report on Sewage Purification at Columbus, Ohio (1905).
8. Report on Sewage Disposal, City of Baltimore (1906).

Sewerage.—General Reference to Systems in Use—Design of a System of Sewerage—Maximum and Minimum Velocities in Sewers—General Principles affecting the Design of Sewers—Execution and Supervision of Sewerage Works—Materials for Sewerage Works—Laying of Pipe Sewers—Brick Sewers—Sewer Accessories and Details—Tank or Storage Sewers—Inverted Siphons — Tumbling Bays, Ramps, and Drop Pipes—Storm or Relief Overflows.

General Reference to Systems in Use.—The removal of the sewage of towns, consisting mainly of excreta, liquid household and trade wastes, is carried out upon either the "conservancy" or "water carriage" systems. The former method, in its various forms of cesspool, midden, dry earth, and pail, having proved itself quite unsuitable for use in large centres of population, has now largely given place to the more effective "water carriage" system, with which the present article is mainly concerned. Another system, which may be described as the "pneumatic method," has been employed to a smaller extent. By this process the sewage is removed by compressed air as in the "ejector system" (*see* "Ejectors"), or by means of a partial vacuum created in small sized iron mains, as in the "Liernur" method (*q. v.*).

The "water carriage" method may be again subdivided under two heads—the "combined" system and the "separate" system. In the former, one set of sewers are provided for the conveyance of all sewage matter, slops, rain water from roofs, roads, yards, &c., whilst in towns drained upon the "separate" system duplicate sewers were laid, one for all foul matters and liquids, and another sewer, usually the larger of the two, for the removal of storm-water direct to the nearest natural outlet or watercourse. Very commonly, it will be found in the majority of towns that the older parts are drained upon the "combined" method, whilst the newer portions are provided with separate sewers for sewage and storm-water respectively.

In districts drained upon the separate system the amount of sewage reaching the outfall works will be much less in volume and more uniform both in quality and quantity than in cases where duplicate sewers are provided. It will be stronger and probably more difficult to treat, but much depends upon local conditions. Storm-water troubles at the outfall works will be greatly minimised, but care must be taken that the outlets, or storm-outfalls, are so placed as to avoid nuisance — bearing in mind that the character of the discharge therefrom naturally varies according to the town and locality from which it is drained. In the separate system the soil sewers do not receive the thorough flushing during storms as in the case of combined sewers, but they may be designed in smaller diameters involving a more rapid flow of the sewage during dry weather periods.

In many instances the practice has been followed of converting the old soil sewers into storm-water sewers, and laying in a new system for the receipt of the sewage proper. This may be done where the existing sewers are sufficiently sound, but in many cases leaky storm-water sewers lead to serious blockages

and subsidences in the roadways, and the policy of continual patching then proves to be of doubtful economy.

The sewerage systems of old towns, or the older parts of a town, usually prove to be much more difficult problems to deal with than is the case with modern systems of drainage. This is especially the case in hilly districts, where often the sewers are laid at shallow depths, at steep gradients, and are subjected to serious wear and tear by the swill of storm-water. The exact courses, depths, and diameters of the sewers are often unknown, there being no reliable record available.

The Design of a System of Sewerage must depend largely upon local conditions and requirements, but there are certain general principles which are applicable to the majority of cases. The question of cost is a leading determining factor. A large item of initial capital outlay may be justifiable if it saves a considerable sum in annual working expenses. The interest and repayment charges on a gravitation scheme, for example, must be considered against the annual working expenses of a pumping scheme of less initial outlay. The former will in a great many cases be the most advantageous—but there are, of course, important exceptions.

In designing a system of sewers for any district some of the principal points to be considered are: the area of the district, its geographical contour, levels, and convenience of division into drainage watersheds, the nature of the subsoil in which the sewers are to be laid, the present and possible future population of the district, the water supply, and the amount of the average annual rainfall.

Other important factors include questions of the site of the outfall works, best course, and possible levels of the outfall sewer, the relative advantages of a wholly gravitation scheme as against part gravitation and part pumping, or as local conditions may determine, and the necessity, or otherwise, of any special works peculiar to the locality.

The population of a district generally equals from five to six times the number of the dwelling-houses, and the quantity of sewage may be reckoned at about 30 to 35 gallons per head per 24 hours, provided there is no infiltration or other water from extraneous sources gaining access to the sewers. The amount of the water supply may often be taken as a rough guide to the amount of sewage to be dealt with. The proper provision to be made in designing the sewage system for future growth of the district drained is not so easily arrived at, but comparisons of the census returns for several periods will give a good guide as to whether the population is increasing, stationary, or declining. (*See* "Population" and "Vital Statistics.") The probable development of business areas, new factories, and works and of likely residential areas, must be carefully considered.

The contour and levels of the district must be fully gone into, as this forms an important factor in the selection of the system to be adopted. Where pumping has to be resorted to the gradients of the sewers are minimised as far as permissible in order to reduce the "lift" at the pumping-station. In flat districts the pneumatic or ejector systems might be found advisable.

The amount of rainfall to be admitted to the sewers is an important factor in determining the sizes to be adopted. One inch of rain in an hour should prove an ample allowance, as this amount only occurs in occasional severe storms. Any increased size beyond that necessary to convey this amount would decrease the efficiency of the sewers under ordinary conditions.

In settling the main lines of sewers the site of the proposed outfall works must be constantly kept in view. Such a site should, wherever possible, be situated at a level to which the sewage can flow by gravitation, and be near a river or watercourse into which the effluent may be passed.

Minimum and Maximum Velocities in Sewers.—To prevent deposit taking place a velocity of not less than 3 ft. per second should exist in 6 in. to 9 in. sewers; this may be

reduced to $2\frac{1}{2}$ ft. in 12 in. to 24 in. sewers, and to 2 ft. per second in larger diameters. These are the mean velocities: the minimum velocity occurs along the bottom of the channel, and may be taken at about 75% of the mean. A 4 in. drain should have a minimum velocity of 1 in 36, a 6 in. diameter 1 in 70, a 9 in. diameter 1 in 130, and a 12 in. about 1 in 250.

As a maximum velocity the flow should not exceed from $4\frac{1}{2}$ to 6 ft. per second for stoneware pipes. For a velocity of 4 ft. per second a 4 in. drain requires a gradient of 1 in 20, a 6 in. diameter 1 in 39, and a 9 in. drain 1 in 75.

General Principles affecting the Design of Sewers.—Sewers should be laid true in line and invert from point to point with access manholes every 300 ft. It is convenient to have intermediate lampholes to facilitate inspection by passing down a light. In setting out the lines and levels every effort should be made to avoid pumping stations or "lifts" of any description, as a purely gravitation scheme will generally be the most economical in the long run. Manholes are also necessary at all changes of gradient or direction, and at all junctions of branch sewers, storm overflows, or other special points. Where a sewer unavoidably passes under a railway, stream, building or other structure there should be a manhole on each side of the crossing point, except where the sewer is large enough for a man to walk through.

Gradients of sewers should be carefully proportioned according to their varying diameters, doing the best possible with the fall available. Excessive fall should be avoided, or damage to the sewers will result. "Drop-pipes" or "ramps" at the manholes and tumbling-bays are employed to consume excessive fall where such exists.

The depth at which sewers should be laid depends upon the description of property to be drained, its distance from the roadway on which it abuts, and the depths of the basements, if any.

Sewers should not be deeper than necessary, not only on account of the increased cost, but also having regard to the greater pressure or weight of earth upon the pipes, and the increased expense of connecting house drains.

Where streets are sewered upon the "separate system," it is customary to lay soil-sewers and storm-water drains side by side in the same trench—the storm-water drain being generally at a higher level. It is important in most soils that the lower or bottom part of the sewer trench should be filled with concrete, or the earth filling stiffened up with lime mixed therewith in the course of the filling. The pipes should be supported with concrete below the centre line, as it is difficult to secure earth filling being put in so as to give adequate support to the lower half of the pipe. Should there be any weakness at this point the weight of superincumbent earth has to be carried by the pipe itself, which, if of stoneware, may very probably be crushed under the load when the newly filled trench settles down upon it. Modern heavy traction-engine traffic may give rise to sudden movement in a sewer trench and cause the pipes to move out of line and give way under the excessive load. As a rule, in most soils, when stoneware pipes are laid deeper than 10 ft. they should be surrounded with concrete, to give increased strength against crushing by superincumbent loads. If possible, junctions for house connections should be provided when the sewer is laid, if the positions can be determined, so as to avoid subsequent disturbance of the sewer.

Branch or tributary sewers should connect with the main sewers at manholes, and the junction should not be at right angles, but at an inclination or sweep leading in the direction of the main flow. Where bends occur extra fall should be given to the pipes to compensate for friction, and the inverts of tributary sewers should have a fall or drop into the main.

When pipes are being laid careful supervision is necessary to see that the inverts of the pipes are true and even, and that the

cement jointing does not protrude inside the pipes. This should be cleared out as the laying proceeds.

Flushing tanks are necessary at the upper ends of sewers having flat gradients. Such tanks are best fitted with automatic flushing apparatus regulated to discharge at fixed intervals.

Manholes on soil and storm-water sewers are commonly built to accommodate and give facilities of inspection to both sewers in order to save the expense of constructing two separate manholes. In the case of combined manholes, provision should be made to prevent sewer gases ventilating through the storm-water drains.

Road gullies, whether entering soil or storm-water drains, should always be trapped at their outlets. They are constructed of brickwork internally rendered in cement, or of stoneware or iron. The intervals between periods of cleansing such gullies depends upon the gradients of the roadways and the amount of rainfall occurring. Large quantities of sand are washed into the gullies in hilly districts, and frequent emptying is necessary.

Execution and Supervision of Sewerage Works.—Upon works of any considerable extent it will be necessary to engage a resident engineer, or representative deputed from the municipal engineer's staff, to supervise the details of the work regularly as they proceed. He should be provided with a small temporary office at the site of the works, and it will be his duty to, from time to time, set out the works ahead of the contractor's workmen, to define the centre line of the courses of the proposed sewers by means of iron or wood pegs, and also to give the contractor the correct levels to which he is to work. All levels should be verified by comparison with the nearest ordnance survey bench mark, and all sight rails and sewer inverts or other levels in the work should be referable to ordnance datum. Should there be any deviation from the original plans, either in regard to level or line of work, these must be carefully recorded on the plans by the resident engineer in charge. He should also keep a note-book to record the dates of progress of the work, to insert measurements to any special junctions, crossings of other pipes or work, and generally any matters likely to be of interest and utility after the work has been covered in. It will be the resident engineer's duty to examine all classes of material brought upon the works, to condemn it, and order its removal from the works when found inferior in quality, or to report to the chief engineer. He must also carefully examine all pipe joints, test the sewers before allowing them to be covered in, and generally, on behalf of the engineer, to keep a close eye on the execution of every detail of the entire contract.

Materials for Sewerage Works.—As all works of sewerage are of a subterranean character, subjected to considerable pressure and wear and tear from the flowing sewage, it is important that all classes of materials used should be of the best obtainable.

Bricks.—Brickwork in sewers, manholes, penstock chambers, and other sewage work should be built of the hardest and most impervious bricks obtainable, and be laid in cement mortar. The "backings" may be of good hard stock bricks, as wire cuts, &c., but the "facings" should be of best blue Staffordshire bricks. The walls of settling-tanks should also be faced with Staffordshire blue bricks.

Concrete is largely used for foundations, bedding, and the backing of brickwork; also for forming the sewer itself in the case of the larger diameters, when it is laid *in situ* around centres. Such concrete should be of the cleanest of materials, and be mixed under experienced supervision and care. There does not appear to be any serious deleterious action by the sewage upon the concrete. Concrete is greatly used also for settling-tanks and filter beds. When in large areas it is very liable to crack; such defects have to be chased out, grouted up, and pointed in cement.

Concrete-Tube Sewers are now largely employed both for sewage and storm-water purposes, but more especially the latter. The tubes are made of all diameters, from 12 in. upwards, and will be found less costly than stoneware pipe sewers (12 in. to 24 in. diameter), and much cheaper also than brick sewers of larger diameters.

The tubes are made of concrete, consisting of crushed granite and cement, and may be obtained either "armoured" or unarmoured. Provided the concrete is of high class and of a sufficient thickness, it is doubtful if, in the long run, there is any great practical advantage in using "armoured" concrete tubes. There has, as yet, been no very lengthy experience sufficient to prove that the metal placed in the concrete will not in time become more or less oxidised, and so split or weaken the concrete. The latter, it has to be remembered, is practically always wet, and the prevention of such oxidation must depend largely upon the quality of the concrete.

Pipe Sewers are constructed of stoneware earthenware, or fireclay pipes; also of cast-iron pipes in special circumstances. Earthenware and fireclay pipes should never be used for public sewerage work, as the material is weak, porous, and unreliable. Fireclay pipes, purporting to be stoneware, have been placed on the market, but the broken section will appear porous and prove absorbent.

Stoneware pipes are very generally used for the great majority of sewerage and drainage work. The materials from which they are manufactured varies in different localities, but the more refractory clays are employed, and the pipes are thoroughly vitrified. A broken section should appear dense in grain, have a metallic ring, and be non-absorbent. The latter quality may be tested by observing the effect of an ink-line drawn on a fractured section with an ordinary pen; if the ink spreads and rapidly sinks in, the material will be of a porous character. The pipes should be even in thickness, true in bore, and be well "salt-glazed" so as to secure a lining approaching natural glass as near as possible. Soft lead glazes are quite unsuitable. When examining a consignment of stoneware pipes every pipe should be gently tapped with a hammer, and if a clear metallic ring is not produced the pipe will almost certainly contain a crack (though sometimes very difficult to find), and should be rejected.

For drainage and public sewerage work the sizes of stoneware pipes used are generally of 6 in., 9 in., 12 in., 15 in., and 18 in. diameters. Larger diameters than 18 in. are not advisable for stoneware pipes. Beyond this size concrete tubes and brick sewers should be used. The thickness of material in stoneware pipes is commonly as follows:—

6 in. dia. . .	$\frac{3}{4}$ in. thick
9 ,, ,, . .	1 ,, ,,
12 ,, ,, . .	$1\frac{1}{8}$,, ,,
15 ,, ,, . .	$1\frac{1}{4}$,, ,,
18 ,, ,, . .	$1\frac{3}{8}$,, ,,

What is known as "tested" stoneware pipes are largely used for public sewerage work. These pipes are specially selected and tested under a considerable head of water, and afterwards stamped with the word "tested" before leaving the maker's works. They cost from 15% to 25% more than the ordinary pipes.

The "specials" in stoneware pipe goods consist of bends, junctions, saddles, channel pipes, and such like. Bends should not be used in a line of sewer, but all changes of direction of line should be made in the manholes, so that the sewers may be thoroughly accessible. Taper pipes should be used for joining sewers of different diameters and junction pipes for connecting up branch drains. Saddle pieces are used where a drain has to be connected to the main sewer after it has been laid, but the "tapping" weakens the sewer, especially if done upon sewers less than 12 in. diameter. Junction-pipes should be inserted wherever possible.

Joints in Stoneware Sewers.—There are many patented forms of joint aiming at better alignment of the pipes and perfect water-tightness. The many forms now available may be observed from the manufacturers' catalogues and price-lists. The cost of the

pipes is invariably greater than that of the ordinary spigot and socket type, and it is doubtful, except possibly under some special circumstances, if any corresponding advantage is obtained by their use. For the great majority of sewerage work the ordinary spigot and socket joint made with cement, with the inverts carefully levelled and the insides of the pipes wiped out at each joint as the work proceeds, will be found to produce a sound job.

Concrete and Stoneware Pipes.—Where the foundation is bad, concrete should be laid to give a sound bed for the pipes. The concrete should be shaped to fit the body of the pipe and depressions formed to receive the sockets. The lower half of the pipes should be well supported by the concrete, and, if laid in a deep trench, a thickness of 4 in. or 6 in. should be carried over the top of the pipes to relieve the pressure. It should be remembered, however, that by so doing the sewers are rendered less accessible for purposes of connecting drains thereto.

Cast-Iron Pipes.—Cast-iron pipes are necessary in certain cases, such as where sewers are laid at shallow depths, at stream or railway crossings, or through bad ground. The pipes used are of the usual water-main strength, viz.:—

Pipes.		Thickness of Metal.					
3″ dia.	..	$\frac{3}{8}$″	..	weighing	1	cwt.	per pipe.
4″ ,,	..	$\frac{3}{8}$″	..	,,	$1\frac{1}{2}$	,,	,,
6″ ,,	..	$\frac{7}{16}$″	..	,,	$2\frac{1}{2}$	,,	,,
9″ ,,	..	$\frac{1}{2}$″	..	,,	4	,,	,,
12″ ,,	..	$\frac{9}{16}$″	..	,,	$8\frac{1}{2}$	,,	,,
15″ ,,	..	$\frac{11}{16}$″	..	,,	$11\frac{1}{2}$	,,	,,
18″ ,,	..	$\frac{3}{4}$″	..	,,	$14\frac{1}{2}$	,,	,,

All pipes should be tested under a hydraulic pressure of 600 ft. head of water, and when under test rapped sharply with a hammer.

Cast-iron pipes should be manufactured from the best tough grey metal from the second melting, and the castings should be free from honeycomb, spongy places, air and sand holes, and other imperfections.

Before the pipes become rusted on the surface they should be treated whilst hot with the Angus Smith solution, consisting of a mixture of coal-tar, pitch, and a small quantity of linseed oil heated to a temperature of 400° F.

The jointing of cast-iron pipes is usually done with molten lead, well caulked into the joint. "Lead wool" has also been used, and sometimes a "rust cement" joint consisting of sal-ammoniac, sulphur, and iron-filings or turnings mixed to a paste with water.

Reinforced Concrete Sewers Laid *in Situ*.—Where large concrete sewers are to be constructed, such as diameters of 4 ft. and over, it will generally be found more economical to build them *in situ* on temporary centering rather than transmit large diameter pipes great distances, as the handling of such is difficult and costly. Local materials for the concrete aggregate can often be used, but it is important that these should be perfectly clean, hard, and durable. A soft aggregate will result in a porous, weak concrete, and a leaky job.

The reinforcements used consist, generally speaking, of a permanent sheet centering, rolled sections or rods in one or other of the various forms available, or of a meshwork of some description. Expanded metal is also used.

The "Bonna" system of armoured concrete tubes, or conduits, has been used in France for over 12 years past, both for sewage and water carriage, and has given satisfaction. The system has also more recently been introduced into this country. An 18 in. armoured concrete rising main, 1 mile in length, has been laid in connection with the Swansea Corporation Waterworks.

The Laying of Pipe Sewers.—The trenches are excavated to the necessary widths and depths, and a shaped or curved bed formed upon which to lay the sewer-pipes, care being taken that they are evenly bedded throughout their length, and not allowed to rest upon the sockets only. The pipes should be truly laid, both as regards line and level, invert to invert in as true a manner as possible. The proper gradient of the invert is secured by setting up "sight rails" at convenient intervals (Fig. 1).

The ordnance level of the sewer invert throughout its length being ascertained from the plans, the sight rails are set up at a convenient height of, say, 10 or 12 ft. above the invert, according to the depth of the sewer, and all intermediate points in the invert of the pipe line are sighted in by the aid of "boning rods" over the tops of adjacent sight rails.

The jointing of stoneware pipe sewers is usually done in cement or cement and sand (1 to 1), a piece of gasket or twisted yarn being first coiled round the spigot end to prevent the cement protruding inside the pipes. After the joint has been completed, the inside of the pipes should be wiped out and left perfectly clear.

The filling in of the trenches should be carefully done, and, in order not to disturb the pipes, the finer portions of the excavated material should be packed carefully around the pipes, and over their tops, to the depth of 1 ft. or more and carefully rammed, and the trenches then filled in, in layers of 6 in. to 9 in. thickness, with adequate ramming and watering, if necessary, so that the whole trench may become thoroughly consolidated. The pipes are greatly supported and strengthened by packing fine concrete along the sides, so as to support the lower half of the circumference; but this, of course, considerably adds to the cost.

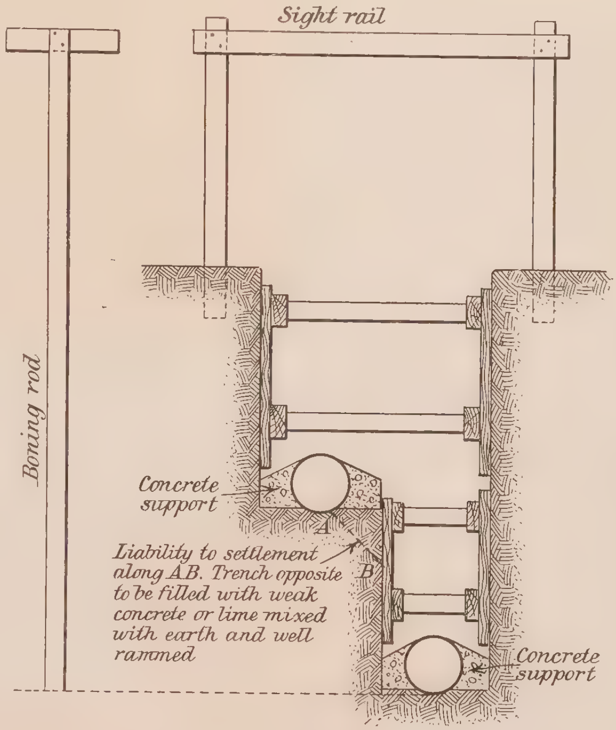


Fig. 1.—Section of Trench for Sewer and Storm-water Drain, showing Concrete Support to Pipes, etc.

The jointing of concrete tubes is simple. The rebate joints are covered with a thin layer of Portland cement and the pipe forced home. The joint is then pointed up inside and out, and left neat and clean.

Brick Sewers are constructed either circular or egg-shaped in cross-section. The circular form is the strongest, simplest, and most economical form, and well adapted to fairly large and continuous flows; but where the volume of sewage is variable, the egg-shaped sewer has advantages, owing to the comparatively small wetted perimeter in the case of small flows. The standard egg-shaped section is shown in Fig. 2, and a new form of this type is given in Fig. 3.

The thickness of brickwork in sewers should not be less than 9 in., and may be determined by the formula $\frac{dr}{100}$ = thickness in feet, where d = depth of excavation in feet, and r = external radius in feet.

The inside ring of brickwork should be of the hardest, non-porous, well-burnt bricks, and blue Staffordshire bricks for the invert as shown in Fig. 4 are preferable to the use of hollow invert blocks.

Invert blocks with hollow spaces or chambers as illustrated in Fig. 5 are not recommended, especially where the work is to be executed in tunnel. Unless the chambers are carefully filled up solid with concrete, the sewage leaks out into these passages and in time undermines the sewer. Care must also be taken that the cement used in such filling be well

"cooled" by spreading on a floor of a dry shed for a week before being used, otherwise the invert blocks may be burst by the expansion of the concrete in setting, thus producing a leaky sewer invert. Blocks having a rebated, or spigot and socket joint, instead of a plain

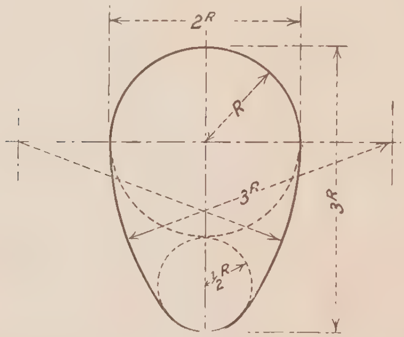


Fig. 2.—Standard Egg-shaped Section for Brick Sewer.

butt joint are best. Solid blue Staffordshire invert blocks are also advantageously used in egg-shaped sewers. For circular sewers, an invert of the best blue Staffordshire bricks as shown in Fig. 6 makes the best job, and is more conveniently built, especially in tunnel.

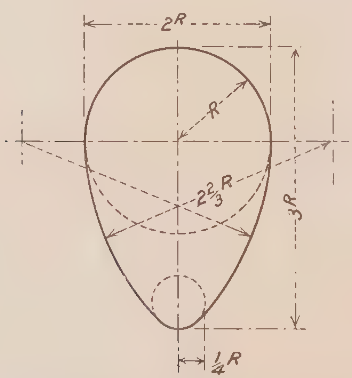


Fig. 3.—New Type of Section for Brick Sewers suited for both Small and Large Flows.

"Cockrill-Doulton" salt-glazed tiles have been used at Great Yarmouth for lining the sewer inverts, the tiles being fixed by means of tags embedded in the concrete.

Some of the different forms or sections of sewers which have been adopted in practice will be of interest (see Figs. 4 to 11). The Clydebank intercepting sewers at Glasgow were constructed of the ordinary circular section (Fig. 7) varying from 3½ ft. to 8 ft. in diameter. The illustration shows a 6 ft. diameter sewer of 14 in. brickwork with Portland cement concrete foundation and backing.

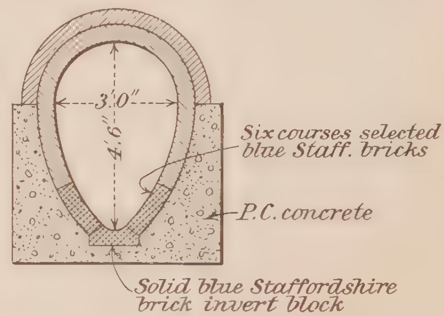


Fig. 4.—Main Sewer, Southampton.

A sewer of the "new egg-shape" form is shown in Fig. 4, as used in the main sewers at Southampton. The invert is of blue Staffordshire blocks, and the sides adjoining same are of six courses of blue Staffordshire bricks. The whole of the brickwork is built in Portland cement mortar.

The section shown in Fig. 5 is often adopted in waterlogged ground. The subsoil

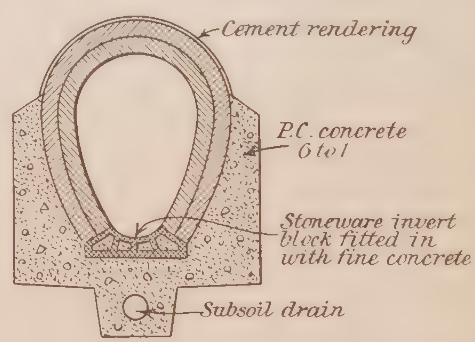


Fig. 5.—Section of Egg-shaped Sewer, showing use of Invert Block and Subsoil Drain.

drain is necessary for the removal of ground water whilst the work is being constructed.

Fig. 8 is a section of a branch sewer as adopted in Paris. It is of the egg-shaped form, provision being also made for a flat benching or path along which sewer-men can

walk, whilst the narrow channel below is suitable for small flows.

A section of the main sewer, Rue de Rivoli, Paris, is shown in Fig. 9. A narrow channel

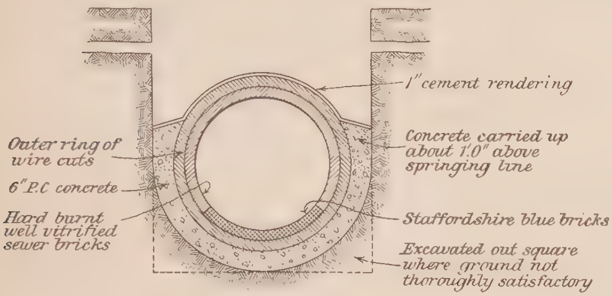


Fig. 6.

for small flows is provided between two walks, and the sewer above is of very ample section. They are also utilised as subways for the underground telegraph and telephone wires, as well as for water-mains, hydraulic and pneumatic-power pipes placed on brackets at the sides in the upper part of the sewer.

The new Clichy collecting and outfall sewer is shown in the section, Fig. 10. Like many of the Paris sewers, it is built of rubble masonry with an inside lining of Portland

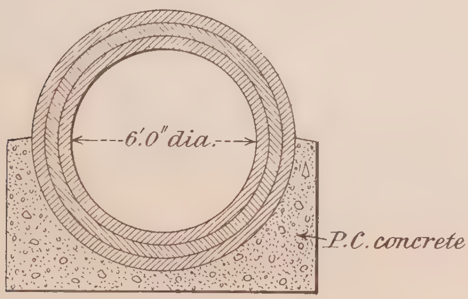


Fig. 7.—Clyde Bank Intercepting Sewer, Glasgow.

cement, and an outside layer of cement concrete on the upper part of the exterior. The usual side walks are also provided for inspection and clearance of deposits, &c. A part of this large sewer under the Boulevard National was constructed in tunnel by the use of the shield. The cover was only from 10 ft. down to 2 ft. 4 in. The sewer has a fall of 1 in 2,000, or about 2·67 ft. per mile.

The northern outfall sewer for conveying the London sewage, on the north side of the Thames, from the Abbey Mills Pumping Station to the Metropolitan Outfall Works at Barking is shown in Fig. 11. It consists of three 9 ft. by 9 ft. culverts side by side, laid with a fall of 2 ft. per mile on a bed of concrete. For a distance of about 1·5 mile in the neighbourhood of Barking the structure is carried on brick arches supported on concrete piers, passing down through the peat to the gravel. The culverts are encased in an embankment of earth raised above the low-lying marshes, over which they cross and carry a roadway on the top.

Sewer Accessories and Details.—Manholes should be provided on sewers at all

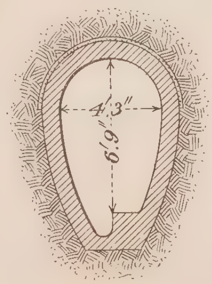


Fig. 8.—Branch Sewer Pans.

changes of line or gradient, and, in any case, not less frequently than 100 yards apart. They should be built of 9 in. brickwork set

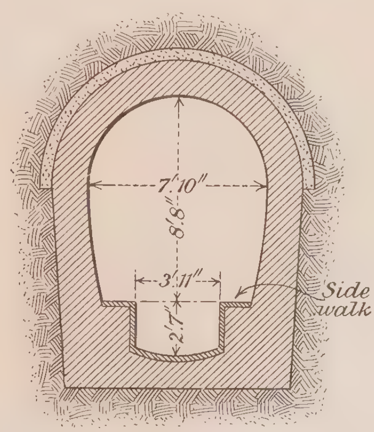


Fig. 9.—Main Sewer, Rue de Rivoli, Paris.

in cement, and may be rectangular or circular in plan. A good method when adopting the rectangular plan is to give the walls a slight curve concave on the inside, which gives additional strength and also increases the working space within the chamber. Cast or

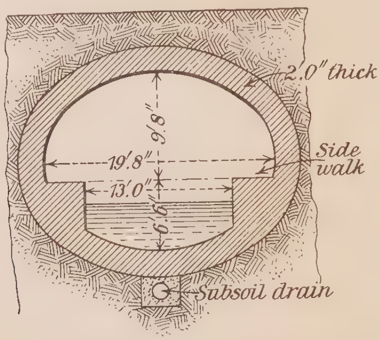


FIG. 10.—Clichy new Outfall Sewer, Paris.

wrought iron foot-irons are built into the walls to facilitate access to the chamber. The invert of the manhole is usually formed in concrete with strong glazed channel pipes. A combined sewer and storm-water manhole is shown in Fig. 12. Where a number of branch sewers at various angles unite at one chamber, manholes of special design

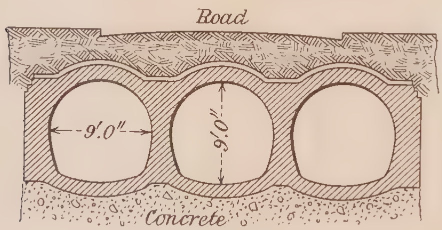


FIG. 11.—Northern Outfall Sewer, London.

to suit the case become necessary. The roofing in of the manhole chamber is also occasionally a matter of some difficulty, especially where the sewer is shallow, and the headroom necessary for the usual manhole arch is not available. A flat or shallow construction, such as obtained by girders and armoured concrete, becomes necessary in order to give adequate room within the manhole, and at the same time sufficient strength to carry the street traffic.

Lampholes are sometimes provided midway between the manholes placed at 100 yard intervals on a pipe-sewer. They are useful for lowering a light to facilitate inspection, but are not often of much service on brick-sewers, these being generally large enough for a man to pass through.

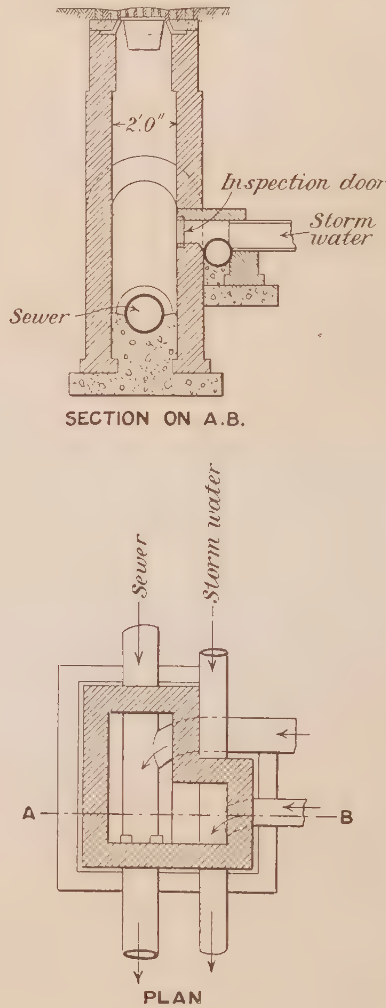


FIG. 12.

FLUSHING CHAMBERS AND APPARATUS.—Flushing is frequently necessary in sewerage systems owing to flatness of gradient or limited use of the sewers. Sewers laid on new estates are sometimes not called upon for many years to convey sufficient sewage to keep them thoroughly clean, and frequent flushing

is needed. This is accomplished in various ways: (*a*) by hose discharging down the manhole; (*b*) by lowering a penstock in the manholes and thus heading up the sewage flow and flush water to a certain height, and then suddenly discharging the same in order to give the sewer a thorough scour; (*c*) by providing special flushing chambers at the head of all sewers having flat gradients and fitting the chambers with flushing penstocks, or, better still, with automatic flushing siphons, which can be regulated to discharge at stated intervals according to requirements. Such a flushing chamber is shown in Fig. 13. The requisite capacity of these tanks depends a

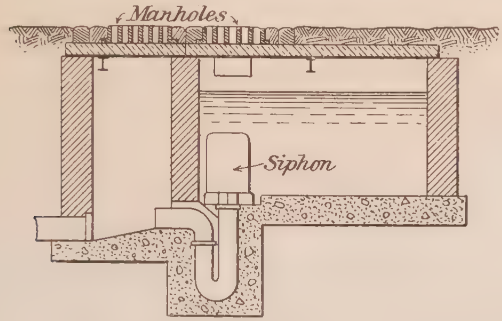


FIG. 13.—Flushing Chamber, with Automatic Siphon-discharge.

good deal upon the circumstances of the case, but about 400 gallons will be advisable for 9 in. sewers, 500 to 600 gallons for 12 in. sewers, 700 to 800 gallons for 15 in., and about 1,000 gallons for 18 in. In large intercepting or collecting sewers there is usually a sufficient depth of flow to keep them clear of deposit. Underground flush tanks are constructed of brickwork, backed with concrete or clay puddle according to circumstances, the inside faces of the brickwork being rendered in Portland cement so as to insure a thoroughly water-tight job. Bituminous sheeting, such as Callender's and others, will also be found a useful means of securing water-tightness.

There are a number of automatic siphons on the market suitable for use in underground flush tanks as above. In some types, the water as it accumulates gradually displaces the air in the siphon, whilst in others the air is confined and compressed by the accumulating water until it blows off, and thus induces siphonic action.

For small flushes not exceeding 100 gallons, metal tipping buckets are occasionally used for flushing in sewer manholes, but are not so satisfactory as the automatic flush siphon above referred to. The tipping buckets are pivoted on bearings fixed in the brickwork of the manhole, and are so arranged that when the water supply has dripped into the buckets to a certain height the centre of gravity is upset, and the contents of the tipper are projected forward down a sloping benching into the sewer. When empty, the bucket or tipper reinstates itself and the refilling proceeds as before.

SEWER IRONWORK.—In connection with all sewerage work a considerable amount of ironwork of various kinds is employed, such as in penstocks, valves, sluices, tide and flap or back-flow valves, valve and penstock gearing, step-irons, landings, manhole covers, and so on.

TANK OR STORAGE SEWERS become necessary where a free and continuous outlet for the sewage flow cannot be provided, as in the case of a sea outfall or low-lying district, from which the sewage must be pumped. In the case of sea outfalls the sewage cannot usually be discharged at high-tide, nor is it desirable to do so at low-tide when the sewage would probably have to run over a portion of the foreshore and cause a nuisance. It is more commonly necessary to discharge only when the tide is at the ebb, and provision must be made for the accommodation of the sewage accumulating at the outfall until it can be discharged. The size of storage required depends, of course, upon the quantity of sewage and storm water to be dealt with, but, as the ebb occurs twice in the 24 hours, very large tanks will not usually be necessary, unless the volume of liquid is excessive, or other local necessities obtain. Fig. 14 shows a chamber on the junction of a 4 ft. 6 in. by 3 ft. egg-shaped outfall sewer with a tank or reservoir sewer 7 ft. 6 in. in height suitable for a sea outfall.

The tank is of the nature of a widening out or enlargement of the outfall sewer and a

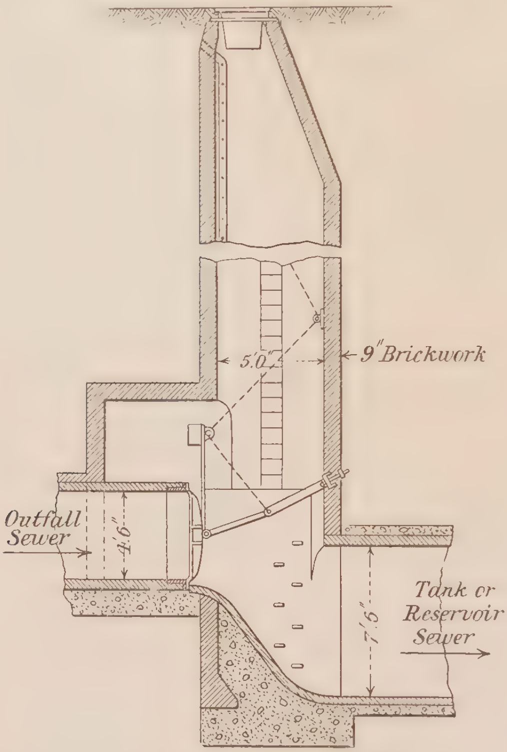


FIG. 14.—Chamber at Junction of Outfall and Tank Sewers.

valve is provided to prevent a back-flow of sewage and sewer air from the tank into the town outfall sewer.

INVERTED SIPHONS are necessary where the line of sewer must cross some obstruction, such as a stream, railway, or subway occurring at such a level as to prevent the sewer following the proper hydraulic gradient. Such siphons are to be avoided, but when necessary should be made as accessible as possible. In the case of a stream or canal the pipes of wrought iron or of boiler plate are commonly laid, from a line of barges arranged across the stream, in a trench dredged in the bed of the stream and afterwards covered over with gravel, &c. Such pipe lines should be laid in duplicate, and communicate on each side of the stream with a roomy penstock chamber to give facility for frequent clearing of the siphons, which is invariably necessary. At the upper chamber a storm overflow should be provided so as to relieve the siphon of excessive pressure at storm times. When sewers necessarily cross canals, railways, and bridges, arrangements must be made, well in advance, with the various authorities owning such works, and their requirements as to terms, conditions, and details of construction at such crossings must invariably be complied with. The work must be done in the most permanent and stable manner, especially in the case of railway crossings.

TUMBLING BAYS, RAMPS, DROP PIPES.—These are different methods of overcoming excessive fall in lines of sewers in hilly districts. Tumbling bays are objectionable on account of the direct fall breaking up the sewage and tending to cause nuisance by the discharge of sewage gas. A better method of connecting between a high-level and low-level sewer is by means of a "ramp" constructed in connection with a manhole as shown in Fig. 15. The ramp or "drop pipe" should have a wide mouthed junction, and preferably be of cast-iron.

STORM OR RELIEF OVERFLOWS.—Provision for relief of internal pressure in sewers in times of heavy rain is very essential, especially in hilly districts, and also in cases where the sewers carry both sewage and storm water. The most

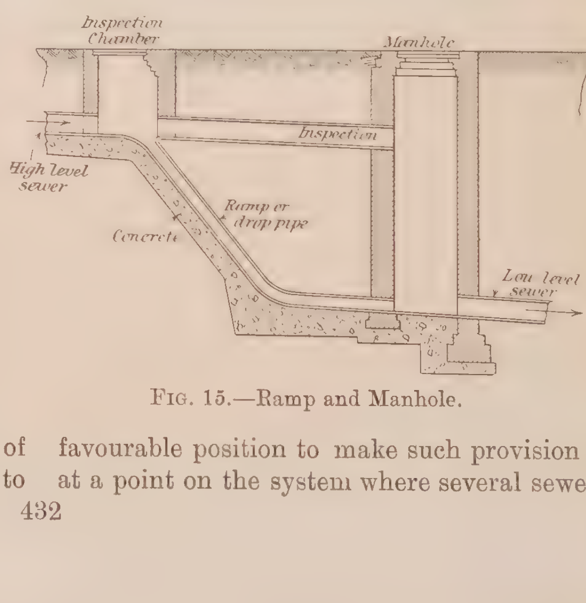


FIG. 15.—Ramp and Manhole.

favourable position to make such provision is at a point on the system where several sewers

from the higher districts converge. The overflow usually consists of a pipe or brick weir placed at a certain height above the sewer invert, in order that, when a dilution of, say, six times the ordinary flow has been reached, the surplus water passes out or over the storm weir direct to the nearest watercourse. The adjustment of storm overflows in a manner so as to insure a uniform degree of dilution or of strength of sewage water passing over is a matter of some considerable difficulty, seeing that the strength of the dry weather sewage itself is very variable throughout the 24 hours, *e.g.*, the character of the liquid passing over a fixed weir in the middle of the night when the sewage proper is weak would be very different from that escaping over such weir at say 10 to 11 a.m., when the ordinary sewage flow is at its maximum volume and strength.

Reference should also be made to the articles "Conservancy System"; "Flow in Pipes and Conduits"; "Drainage (House)"; "Dry Weather Flow"; "Earth Closets"; "Ejectors"; "Flushing Sewers and Drains"; "Lampholes"; "Liernur System"; "London Main Drainage"; "Penstock"; "Pipe-joints"; "Pipes, Cast-iron and Stoneware"; "Separate System"; "Sewers and Drains"; "Subsoil Drainage"; "Testing Drains and Apparatus"; "Ventilation of Sewers and Drains"; "Water-carriage," &c. W. H. M.

Shallow Wells. (*See* "Wells.")

Shone's Ejectors. (*See* "Ejectors.")

Shone's System of Ventilation. (*See* "Ventilation of Sewers.")

Sight Rails.—Sight rails are used for the purpose of obtaining true gradients for sewers, drains, &c. Uprights are fixed at the sides of the trench at convenient points and the "sight rails" nailed thereto, with their upper edges (which must be level and perfectly true) at a fixed height above the invert of the work. For convenience in sighting they are often painted in alternate bands of black and white. At least three sight rails should always be in place in each length of the work, so that any displacement of either of them may be at once detected.

The levels of the work are obtained from the sight rails by means of "boning-rods"—each consisting of two pieces of light scantling nailed together in the form of a T, the length of the longer piece being equal to the depth from the top of the sight rail to the bottom of the work. In use a boning-rod is held upright in the trench, and raised or lowered until the top of the cross-piece on it is in exact alignment with the tops of the rails. The bottom of the rod then gives the required level for the work. In laying pipe-sewers two rods will be required—one for the bottom of the trench, and the other for the pipes. The latter should have a short L-shaped foot to rest on the invert of the pipe, and the pipe is raised or lowered until the top of the rod is in correct alignment. (*See* Fig. 1 under article on "Sewerage.")

A. J. M

Sinks.—The classes of sinks in general use, of each of which one or more may have to be provided in large houses, are:—

Scullery Sinks, Pantry Sinks, Nursery Sinks, Drip or draw-off Sinks, Larder or Dairy Sinks, Vegetable Sinks, Pickling Troughs, Wash-tubs and Housemaids' Sinks.

These should all be chosen in accordance with the uses to which they are to be put.

Scullery Sinks must be governed in dimensions by the size of the premises in which they are fixed and the amount of washing-up to be done. They are best made of glazed stoneware—white or cane—and should have a plug and overflow so that they may be filled with water. In large premises they are best provided in pairs—one for the washing of plates, and the other for rinsing them.

Pantry Sinks, in which glass and silver are washed, may be constructed of lead-lined wood, as this material is less liable to cause damage than fireclay or stoneware. They

have the drawback, however, that under the constant use of hot water the lead is liable to buckle up, twist, and crack. Stoneware sinks are therefore frequently used, a wooden bowl being provided in them for the actual washing.

Nursery Sinks, for soaking and washing soiled baby-linen, should be of white glazed stoneware, and should have plugs and overflows. They should be comparatively deep.

Drip Sinks fixed under taps, for drawing water for the bedroom, may consist of shallow glazed stoneware or lead trays on the floor.

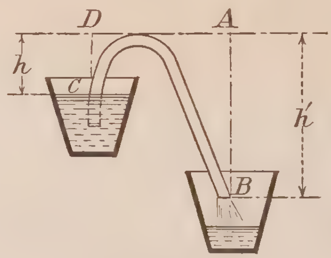
Larder and Dairy Sinks should be of stoneware, white glazed inside and out. They should be deep, have rounded corners, and be provided with plugs and overflows.

Vegetable Sinks and Wash-tubs should be deep, have plugs and overflows, and should be made of picked American birch, pine, teak, or sycamore, with tongued and grooved joints drawn together with iron bolts and screws outside the sinks. They are best provided in pairs—one for washing, and the other for rinsing.

Pickling Troughs may be made in the same way as vegetable sinks, or of slate slabs similarly jointed; or they may be of glazed fireclay, care being taken that the glazing is such as is not acted upon by salts or acids.

Housemaids' Sinks should be of white glazed fireclay, and provided in conjunction with "Slop Hoppers," for which see under that heading.

Siphon.—A siphon consists of a pipe or tube bent to form two legs of unequal length, by means of which a liquid may be conveyed over an intermediate elevation to a lower level. It is used for emptying casks, cisterns, &c., or for drawing water from one reservoir to another at a lower level, where suitable conditions obtain. The action of the siphon depends entirely upon the pressure of the atmosphere forcing the liquid up the shorter leg, whilst the excess of weight of the liquid in the longer branch causes the flow. To explain this action it is assumed that the siphon is filled with water and the short leg immersed, as in figure. Then, the pressure acting at C forcing the liquid up the tube is the atmospheric pressure, less the weight of the column of liquid D C. Also, the pressure at B is that of the atmosphere minus the weight of the column A B. But as the leg A B is longer than C D, the pressure at B is less than that at C, so that a flow takes place from C to B in proportion to the difference between the pressures at C and B, and the greater the difference between these two levels the more rapid the flow. The siphon will not work if the height C D exceeds that of a column of liquid which balances the atmospheric pressure. The limit of such height would be about 34 ft. for water and 30 in. for mercury. The siphon is started by filling it with liquid,



Siphon.

closing the ends, and immersing the shorter leg as shown, when a flow will take place from the free end at B. Or, it may be charged with water and started by closing end B, exhausting the air from the siphon by means of a pump, when the water will rise through the end C and flow to B.

Inverted Siphons are largely employed in engineering works, such, for example, as on aqueducts or pipe-lines for water supply purposes where a deep valley has to be crossed, or where it may be necessary to carry the pipeline under the bed of a river, the two ends of the inverted siphon coinciding with the hydraulic grade line of the aqueduct.

Siphonage (of Traps.)—One of the most frequent causes by which the water seal of badly ventilated traps is destroyed; the

siphonage of the trap being brought about by the discharge of another fitting on the same waste-pipe, or by the momentum or impetus of the water passing through the trap itself. The latter is most likely to take place where the waste-pipe is of considerable length. To prevent siphonage ventilation is essential. In the case of a long waste-pipe, on which is only one fitting, the ventilation of the waste-pipe will be sufficient. Where more than one fitting discharge into a waste-pipe common to all, each trap except the highest on the stack must be separately ventilated, the various vent-pipes being conveniently branched into a main anti-siphonage pipe. Ventilation pipes must be branched into the outlet side of the traps at a point removed a few inches from the crown of the latter, and should be curved at the point of connection in the direction of the flow through the waste-pipes.

Sites of Houses.—Soil.—Surroundings.—Aspects.—Planning.—Maisonettes and Flats.— It is not always possible to select the site of a house, especially in towns, but in this case preference should be given to a gravelly soil and high ground, to open squares, or to wide roads running north-east and south-west, or north-west and south-east, and to the sunny side of the way. Avoid houses built on made ground, or see that the site is covered with 6 in. of concrete.

Soil.—When choice can be exercised, the soil should be naturally dry and well drained, elevated somewhat above the surrounding district, but not bleak. The spur of a hill is better than the sloping sides. Clay is impervious, damp and cold, and if a clay site is unavoidable the highest ground should be chosen. If a thin layer of sand or gravel rests on a subsoil of clay, it is to be avoided, as the rise and fall of the subsoil water will cause movement of the ground air, and when this is expelled it is unhealthy. Ground water should not be nearer the surface than 4 ft.

Surroundings.—The neighbourhood of a marsh is unhealthy from the damp and the malarial vapours which may arise. Brick-fields, gas-works, chemical factories, soap works, and similar places give off effluvia which are decidedly unpleasant and may be deleterious to health. Factories pollute the air with smoke and some, such as copper works, destroy the vegetation. Cesspools, if unavoidable, should be at least 50 ft. away from a dwelling, should be built of brick-in-cement and rendered on the inside to prevent pollution of the surrounding soil. Wells should be on the highest ground available and carried down with impervious sides deep enough to reach pure water only.

Aspect.—The house should be so situated that the sun and air have free access to it, and it should be so placed that all sides are exposed to the sun at some period of the day. It should not be too closely surrounded by trees; deciduous trees in large numbers in the neighbourhood of a dwelling render it damp. A pine wood is not open to this objection. As a rule no tree should be nearer to a house than its own height; within a distance of 20 ft. the roots are liable to disturb the drains and foundations of the walls. Large trees in moderation, afford shelter from high winds, and are thus useful, especially on the north and east sides.

Planning.—North-west is a good quarter for the house to face, and the rooms may be appropriated according to the light required. The larder and store-rooms may face north, more or less, so as to be kept cool; the w.-c.'s may face north to east, so that there is no hot sun on the outside soil pipe to cause excessive expansion and contraction; the bath-room may face east to get the early morning sun; the breakfast-room and morning-room should face south-east to south so as to be bright and cheerful in the morning; the dining and drawing-rooms should face south-west to west to get the afternoon sun; the kitchen and scullery should be on the cool side of the house but receive a fair amount of sunlight, say east to south-east; the principal bedrooms should face north-west and the back bedrooms east to south-east. A north aspect is suitable

for a study, library, or work-room, where a steady diffused light is appropriate; a bay window may often form a cosy nook, where the sun may reach one of its sides.

Maisonettes and Flats.—Maisonettes, or houses containing two or four separate dwellings, are not generally unhealthy, but modern west-end "mansions" or flats should be avoided; it is difficult to get thorough ventilation without draught, and the basement flats are little better than cellar dwellings. "Back-to-back" houses should be avoided at all costs. H. A.

Slate Beds for the Primary Treatment of Sewage.—The original coarse coke or clinker contact beds were designed for the primary treatment of screened sewage in order to render the liquid portion fit for final treatment on land, fine-grained contact beds, or other suitable method. The coarse beds allowed the smaller suspended matters to pass into the interstices between the coke, and, settling there, served as food for the various organisms which rapidly accumulated, the proposal being an alternative to the then generally prevailing method of chemical treatment and sludge pressing. The result was entirely satisfactory, and in the absence of any improvement would still form the only method for effecting the inodorous destruction of those matters which, in their collective form, constitute "sludge." It was found, however, that after some few years the resulting *débris* arising from the destruction of the solid organic matters were retained between the particles of coke, &c., and gradually reduced the working power of the beds. This action called for a remedy. In addition, it was observed that with coke or similar material there are a number of particles of solid matter presenting only an outer surface, the interior of each particle being wasted. It was obvious that if each particle was hollow it would present an interior as well as an exterior surface on which sewage matters could deposit, and thus greatly increase the water content of the bed.

These considerations suggested the use of agricultural drain-pipes, but the fact that a pipe is only a bent plate pointed at once to the feasibility of using superposed plates, which would form a series of shelves on which the sewage particles could settle, and be digested by the innumerable variety of organisms, from bacteria to worms, which would speedily develop.

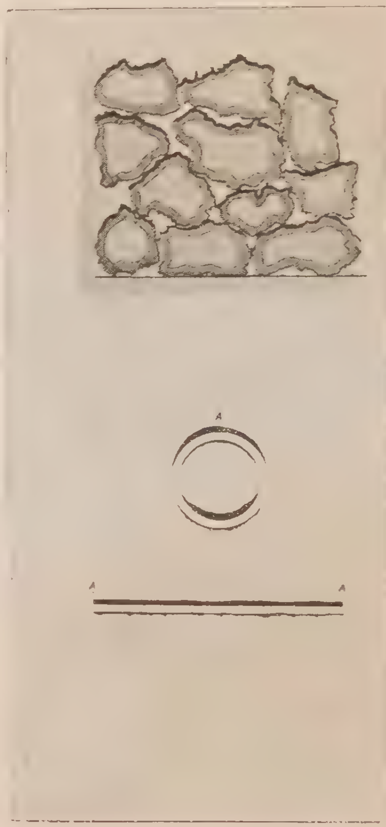
The following illustration will demonstrate the process:—

GENESIS OF THE PLATE BACTERIA BED.

Section of Coke Bed showing waste space in centre of particles of coke—and deposit on surface of coke.

Section of Pipe with deposit on upper surfaces of exterior and interior, thus securing double working capacity and surface.

Pipe cut at *A* and opened out flat, forming a plate.



The dark line on the surface of the plate indicates the layer of "living earth" rapidly formed by the decomposition of the sewage deposit, which layer receives an increment of about one-hundredth of an inch at each filling of the bed with normal sewage. This freshly-deposited thin layer is consequently rapidly attacked by the organisms (worms, infusoria, moulds, and bacteria) in the "living earth," and thereby reduced.

Fig. 1.

It was finally decided to use the 'waste slate *débris*' from quarries, the slates being cheap, absolutely permanent, capable of being easily and thoroughly cleansed at any time if necessary, thus restoring the bed.

An experimental bed was constructed at Devizes, Wilts., by the co-operation of the town council and worked for 19 months. The crude, unscreened, and unsettled sewage arriving at the outfall was used to fill the bed two or three times daily, with the result that the solids were reduced to an inoffensive residue, which on exposure to the air dried without nuisance of any kind to a condition resembling garden mould.

The greater portion of this residue came away from the slate bed during the last portion of the discharge, and could be easily collected instead of being allowed to flow on to the surface of the fine clinker bed which received the effluent from the slate bed. The humus in the bulk of the slate bed effluent went on to the fine bed, where it was retained and scraped off from time to time.

In consequence of the method of constructing the slate bed with layers of slate about a quarter of an inch thick, separated by blocks of slate 2 in. cube, the water capacity of the bed is, when new, about 85°/ₒ of the total cubic content of the bed. After a time the average depth of *débris* and organisms on each slate is about another quarter of an inch, which reduces the total working capacity to about 70°/ₒ, the net result being that the slate beds need be only one half the size of the old coke, &c., contact bed, thereby effecting a saving of nearly 50°/ₒ in the constructional cost of the tank, which, when filled with slate, forms the "bed."

The continued use of the method at Devizes, where it has been treating the whole of the sewage unsettled and unscreened since 12th September, 1905, and at other places under varying conditions of strength of sewage, manufacturing waste, &c., has, in the opinion of the writer, demonstrated the fact that the beds show no tendency to become choked, the resulting residue escaping from the beds as rapidly as it is formed.

The grit which arrives with the sewage is largely retained in the channel supplying the inlets to the slate beds, and is removed from time to time with a spade, the work involved being but slight. The working cost at Devizes has been reduced from £700 per annum under the old system of chemical precipitation and sludge pressing to £200 per annum, with the further advantage of removing all cause of complaint as to the condition of the brook receiving the effluent.

From the results of 5 years' work with this system the conclusion may be drawn from many different independent investigations with sewages of widely varying quality that it is not only effective, but is a valuable means of dealing with the sludge problem and preparing the liquid portion of the sewage for secondary treatment. The material will not break down when once properly built in the beds, nor can the drainage from the under surface of the bed be impaired; whilst the growth of the organisms will take place on both surfaces of the slates or other material used as "plates," and will not choke up the spaces between the respective layers as in the case of coke, &c.

Evidence is accumulating to show that the beds are self-cleansing for the reasons mentioned, the capacity of beds steadily working for 4 years having undergone no material change after the first 6 months.

During the winter months, in consequence of the sluggish action of the organisms, there is a tendency for the deposit to accumulate, but with the arrival of the spring, when all vegetable and animal life is most active, the beds rapidly discharge their accumulated burden of humus, &c. This action in no way impairs their working power, as the quantity of matters accumulating is only a small proportion of the total—in consequence of the temperature of the beds being to a considerable extent self-generated and retained after the manner of the ordinary gardener's "hot-bed," *i.e.*, by the vital processes of the organisms at work therein.

In order to illustrate by concrete examples the action which takes place in these beds, the writer has carried out the following series of experiments on the rate of destruction of some typical food-stuffs when submitted to the action of the organisms freely abounding in the *débris* which had been obtained from slates ordinary deposited matters in settlement tanks.

If a portion of the deposit is placed on a small piece of slate, about 3 in. or 4 in. square for convenience, or other suitable support, and warmed very gently by applying heat to the under surface, a considerable movement

EXPERIMENTS ON THE RATE OF DESTRUCTION OF SOLID MATTERS IN SLATE BEDS, PREPARED WITH DEPOSIT TAKEN FROM THE SLATES IN THE BEDS AT MALDEN, SURREY.

Substance.	First day, after 20 hours' rest.	Second day.	Third day.	Fourth day.	Fifth day.
Bread	Zooglea masses, starch cells spiral vessels, motile bacteria, leptothrix, green confervæ, &c. Bread undergoing disintegration.	Numerous bacteria, starch cells very attenuated and losing form.	Bread completely disintegrated, abundance of leptothrix, oscillaria, monadina, clostridium, quantity of round granular matter (? worm casts).	—	—
Butter	Mass of fat cells	Fat cells with brown granular matter (? worm casts).	Brown granular matter with spirilla, leptothrix, fat cells.	Irregular cellular membrane with colonies of micrococci and bacilli, &c.	Butter reduced to a thin wafer.
Cheese	Masses of various bacteria, *i.e.*, bacilli, micrococci, streptococci, &c.	Swarming with colonies of motile bacilli.	Bundles of stellate crystals interspersed with numerous bacteria, motile and non-motile.	Fat cells crowded with bacilli and diplococci.	The cheese reduced to a thin pasty layer.
Lettuce	Chlorophyll attacked, bacilli, diplococci, zooglea, leptothrix, &c.	Peaty matter, various bacteria.	Granular matter, leptothrix, various bacteria, monadina, amœba, infusoria, &c.	Indefinite *debris* (? worm casts); lettuce decomposed to granular condition almost free from bacteria (? action of worms).	Last trace of lettuce disappeared.
Lean pork (cooked) ...	Mud black underneath, deep chocolate on surface,* various bacteria, leptothrix, and encysted infusoria. * ? worm casts.	Meat in fibrous state, muscular fibres embedded in zooglea masses of bacteria, large numbers of spirilla and motile bacilli, anguillulæ and worms.	Muscular fibre extremely attenuated, numerous spirilla, motile bacilli, and monadina, zooglea, oscillaria, &c.; the whole swarming with micrococci.	Muscular fibre entirely destroyed, the residue being alive with motile bacilli, spirilla, monadina, oscillaria, anguillulæ, worms, &c.	Pork reduced to a thin greyish scum consisting of various organisms.
Tendon from roast pork; very hard and tough.	Abundant organisms, various bacteria single, and in zooglea form.	Enormous numbers of micrococci and monadina.	Swarming with micrococci, spirilla, monadina, granular cellular matter (? worm casts), fungoid mycelium.	Quantity of brown granular matter (? worm casts), anguillulæ, worms, monadina, many bacteria, zooglea masses, oscillaria, &c.	Tendon reduced to a soft grey mass.
Fat of ham ..	Leptothrix, streptococci, and numerous zooglea masses.	Fat cells interspersed with various bacteria.	Fat cells, brown granular matter (? worm casts), bacteria, &c.	Fat cells with zooglea masses, spirilla, &c., various infusoria, opalina, oscillaria, &c.	Fat largely reduced to a soft pasty mass.
Brewery refuse in sewage.	Yeast cells practically destroyed, leptothrix, zooglea masses, various infusoria.	All odour of brewery refuse disappeared, grey surface deposit.	—	—	—

in actual use. The examination of these clearly indicates that the process of destruction of the organic matters is solely due to the result of their digestion by the numerous and various organisms present. The absence of offensive odour and the ready manner in which the deposit dries to a powder clearly point to a vast difference between this matter and the will soon be seen to take place on the immediate surface, and gradually a heaving mass of minute worms will struggle to escape from the heated underlayer. These are clearly aërobic organisms whose power of digestion is considerable, and it is to a great extent their casts which form the inoffensive humus which escapes from the slate layers with the effluent,

thereby preventing the accumulation which is the cause of the choking of the old coarse contact beds.

A fragment from the surface of the deposit, collected by touching it with the point of a wire and placed on a microscopic glass slide with a droplet of water, covering the whole with a thin glass cover in the usual manner, may be examined with a $\frac{1}{4}$ in. or higher power. It will be at once seen to be largely made up of innumerable living organisms of great complexity and variety, other than the worms.

digestion—the waste products of one group being but food for a lower.

The process may very conveniently be watched from day to day by placing the previously mentioned small piece of slate in an ordinary plate or saucer, and putting on the "living earth" on the slate small fragments of meat, bread, &c., and flooding the plate with water gently so as to completely cover the whole. After an hour or two gently decant the water from the plate so as to thoroughly drain the plate and deposit thereon. Leave it freely exposed to the air, preferably in a moderately warm atmosphere. On watching from time to time it will be seen that the piece of red meat has become coated with a grey deposit, this being often complete in 4 or 5 hours. Now touch the grey matter with the point of a wire, and transfer the minute quantity thus taken up to a microscope slide as before, and examine under a high power, when it will be seen that this grey matter is nothing but an enormous number of bacteria, many in a state of restless activity where they are not crowded in zooglea masses which prevent their rapid movements.

EXPERIMENTS WITH DEPOSIT COLLECTED FROM SLATES IN BED TREATING THE SEWAGE AT A PRIVATE HOUSE.

A preliminary microscopical examination showed that the deposit was swarming with minute red worms, anguillulæ, infusoria, and various bacteria.

Substance.	First day.	Second day.	Third day.	Fourth day.
Lean of raw beef	In 4 hours the red colour had turned to grey.	The beef had sunk into the mud, grey in colour, and swarming with bacilli, spirilla, monadina, &c.	Beef scarcely visible, being now one mass of various organisms.	Meat entirely disappeared.
Cheese	In 4 hours the cheese was light grey in colour.	Cheese had sunk into humus, swarming with bacilli of various kinds.	Cheese reduced to a thin layer.	Entirely reduced to a pasty condition.

On November 2nd, 1908, 7 grammes of raw liver were placed on a layer of the above deposit, laid on the bottom of a 4in. Petri dish, the area being 12 in. approximately. The quantity of liver thus treated was equal to the treatment of a sewage 100 times normal strength.

First day (after 24 hours).	Second day.	Third day.	Fourth day.	Eighth day.	Fifteenth day.
Liver had lost colour, odour unpleasant.	Odour offensive.	Very offensive.	Odour decidedly reduced.	Odour had entirely disappeared.	Liver reduced to a very few resistant pieces, which were covered with whitish grey spots consisting of *bacillus megatherium*. Later, a growth of the mould, *mucor caninus*, developed.

NOTE.—This experiment was very drastic. The liver was laid very thickly, with scarcely any room between the pieces, none of which was smaller than $\frac{1}{16}$in. diameter, whilst many approached $\frac{1}{4}$in.

On November 6th another dish was similarly charged with 1 gramme of beef steak raw, 1 gramme of beef fat, and 1 gramme of cheese. On the sixth day the cheese had entirely disappeared, the beef steak was reduced to a greyish soft mass, and the fat was disintegrated.

From these simple examinations it will be evident that instead of an inert mass of matter we have a hive of active and voracious living organisms, from the lowest type of bacteria up to the highly organised worms, larvæ, &c., which, like a collection of animals in a zoological gardens, feed upon the daily supply of food given to them, and so long as this supply is steadily and regularly maintained, so long will they perform their life functions, and in so doing destroy the waste organic matters which, in their collective form, we call sludge; the process involved being merely that of

Continue these observations from day to day, each day flooding with water and draining after 2 hours or so. In a few days the solid particles of meat, &c., will become invisible and merged in the mass of black humus into which it is finally resolved.

It is evident that this is precisely what takes place in a slate bed. When the bed is first filled with sewage, and allowed to stand full in a quiescent state for a couple of hours, the solid matters settle on the slates. Until the "living earth" is fully developed, the destructive action is slow, but in warm weather especially the organisms rapidly develop and attack the food thus provided for them, exactly as the organisms in a river mud attack the matter deposited thereon from a tidal water receiving sewage matters, and if the ratio of organisms, food and air supply are properly regulated, the action proceeds indefinitely without the evolution of nauseous odours.

The account given in the tables of a series of experiments made to ascertain the rate of destruction of various food-stuffs when placed on the mud on the slates will be of interest.

W. J. D.

Slop Hoppers.—Provided in many houses for the reception of bedroom slops and other fouled liquids. They must be treated in every way as water-closets, which fittings the most cleanly slop sinks resemble in shape. Like water-closets, these hoppers must be provided with flushing rims, and should be flushed by water waste-preventing cisterns. Unlike closets, however, they should be fitted with a loose grating over their outlets, in order to intercept pieces of soap, scrubbing brushes, cloths, and similar articles which may be carelessly thrown in with the slops. The height of their upper edge in front should not exceed 1 ft. 6 in. from the floor, in order that pails may be conveniently emptied out. The higher a pail has to be lifted the greater is the probability of the surroundings being splashed. Where space is available, it is both desirable and a convenience to fix a wash-up sink in connection with the slop sink, for the purpose of rinsing the emptied out receptacles and for refilling bedroom jugs. The waste of this sink may be conveniently arranged to discharge into the slop hopper, and need not be trapped. Various manufacturers make fittings in which these two forms of sinks are combined and made in one piece. These, as a rule, are of good design, and preferable to two separate appliances.

Sludge (from precipitated sewage).—The weight of wet sewage sludge produced per million gallons of sewage varies considerably in different places. At Manchester it is mentioned as 21 tons, Salford and London about 26 tons, Chorley 60 tons. About 40 tons per million gallons, when containing about 90% of moisture, is perhaps an average amount, but in comparing weights the percentage of moisture must be taken into account. The reduction in weight at varying degrees of dryness is readily calculated by the following rule:—

$$x = \left(\frac{100 - P}{100 - Q}\right) y.$$

In which—

x = weight of sludge cake produced.
y = original weight of the wet sludge.
P = percentage of moisture in the wet sludge.
Q = percentage of moisture after pressing.

A cubic yard of wet sludge weighs about 16 cwt., and a cubic yard of broken cake as delivered from a filter-press weighs 12 cwt. Ordinary precipitated sludge commonly contains about 95% of moisture, and septic sludge 90%. The quantity of wet sludge produced varies according to the sewage and the chemicals used, but the average quantity yielded daily per 1,000 persons in eight towns where lime and sulphate of alumina were added to the sewage was ·92 tons. In dealing with sludge it is important to remember that a small reduction in percentage of moisture means a very marked reduction in bulk and weight, hence, also, in cost of disposal. For example, 100 tons

of sludge containing 95% of moisture equals 50 tons only when the moisture is reduced to 90%, as will be apparent from the above rule. Sewage sludge is of low manurial value, and contains only small quantities of nitrogenous compounds and phosphates, with a large amount of mineral matter, water, and some cellulose. Its disposal constitutes one of the chief difficulties in sewage treatment. Some of the means adopted are: Manufacture into marketable manure, depositing at sea in deep water, pressing into sludge cake and disposal on land, running of liquid sludge into trenches and burying on land, air-drying on the surface of land or in lagoons, and then digging or ploughing into land, burning of sludge in destructors, and extracting marketable constituents for sale. At Kingston-on-Thames the precipitation of the sewage and disposal of the sludge costs 1*s.* 8*d.* per head of the population per annum, and the sludge is made into a marketable "native guano." At Dalmarnock, Glasgow, the sludge is produced by precipitation with lime and ferric sulphate, and part is sold in the form of pressed cake at 8*d.* to 1*s.* per ton in bulk at the works, and a part is made into a manure ("Globe Fertiliser"), and sold at from 8*s.* to 10*s.* per ton in bulk. The cost of pressing the "cake" is 2*s.* per ton, and of the production of the "fertiliser" about 10*s.* per ton. For towns on the seaboard the disposal of sludge by depositing in deep water is usually the cheapest plan in the circumstances. The London sludge is deposited at the Barrow Deep 20 miles below Southend, the Glasgow (Dalmuir) sludge at a point three miles below "Garroch head," 40 miles from Glasgow, and that from Manchester (Davyhulme Works) through the Ship Canal, and dumped in deep water outside the north-west lightship. Other towns disposing of sludge by sea are Salford, Dublin, and Southampton. The total cost, including interest and sinking fund, of this mode of disposal of sludge containing 90% of water ranges from about 4*d.* to 7*d.* per ton, according to local conditions. The pressing of sewage sludge, though not a means of final disposal, greatly facilitates the subsequent handling of the material, and puts it into a form which makes its cartage or sale to farmers and others possible. The moisture in pressed sludge-cake is reduced to from 65 to 50%. The precipitated sludge from settling tanks is swept out into a sludge well and the supernatant liquor drawn off. The thick sludge remaining is mixed with ·5 to 1 % of lime, and then forced by compressed air into the filter presses, where some 30 to 35 % of the sludge water is pressed out. The "cake" falls from the press into trucks, and is sold or given away to farmers, tipped at some available shoot or buried. If tipped on land in bulk it should be covered with a layer of earth, and sown with seed or turfed to avoid smells. At York uneven land is being levelled in this way. Sludge pressing is carried on at a number of towns, including Burnley, Chorley, Ealing, Hanley, Leyton, Nelson, Wolverhampton, Wimbledon, and Willesden. The cost of pressing per ton of pressed cake varies from 1*s.* 6*d.* to 4*s.* 6*d.*, about 2*s.* per ton being a very common figure, exclusive of interest and sinking fund on cost of plant. At Birmingham, Guildford, and Withington the precipitated sludge is run into V-shaped trenches on land, and after covering with earth and allowing time to dry, is then ploughed in and the land cropped. Care is necessary to avoid nuisance, especially with septic sludge. About 1 acre of medium quality of land would probably be required to deal with 1,000 tons of wet sludge per year. The cost of this method of disposal varies from 4*d.* to 7*d.* per ton of wet sludge. At Ealing, Leyton, and Huddersfield sewage sludge is mixed with house refuse, in the proportion of one of sludge to about two of refuse, and burnt in refuse destructors. At Huddersfield coke breeze is substituted when refuse is not available. The cost of burning the sludge amounts to 2*s.* to 2*s.* 6*d.* per ton.

At Bradford, where the sewage contains a large proportion of wool-scouring liquor, the fat is extracted and sold at a profit. In

Watson and Butterfield's patent sludge distilling process the object is to recover the nitrogen from the sludge in the form of ammonia, and to use the carbonaceous matter for generating heat. The manurial value of sludge on land is not great, it is slow in acting and does not appear to be very suitable for root crops. W. H. M.

Smoke Prevention.—Smoke may result from the combustion of a variety of fuels, and in several processes of manufacture; but the remarks which follow refer particularly to that from ordinary bituminous coal. Coal smoke is made up of particles of unburnt carbon, ash, and condensed tarry vapours and steam, suspended in the gases issuing from the fire. It is an indication of imperfect combustion. To deal intelligently with the problem of prevention we must understand the causes of its formation. Briefly then smoke is formed as follows:—When bituminous coal is placed on a fire it first undergoes distillation, and the familiar yellow smoke, composed of condensed tarry vapours, is given off. Soon these vapours and the accompanying gases take fire, and burn with a bright flame; it is from this flame that the carbon particles of the smoke come. The flaming matter consists of hydrocarbons, the chief of which are Methane or marsh gas—CH_4, Ethylene or olefiant gas—C_2H_4, and Acetylene—C_2H_2. If combustion is perfect these burn to carbon dioxide and water, thus—

$$CH_4 + 4O = CO_2 + 2H_2O.$$

If insufficient oxygen is available this may become—

$$CH_4 + {}_2O = C + 2H_2O,$$

the result being soot and water; and if the heat is sufficient to split up the hydrocarbons, but no oxygen is supplied, they may simply dissociate into carbon, or soot, and hydrogen thus—

$$CH_4 = C + H_4.$$

Marsh gas is taken in these formulæ, but the other hydrocarbons produce the same substances. Probably the soot in coal smoke is produced in this way. The maximum amount of soot is therefore limited by the amount of volatile carbon in the coal, 30°/₀ of which is about an average. The amount of fuel lost in soot, however, probably seldom exceeds $\frac{1}{2}$°/₀ of that burnt. The formation of soot means that unburnt gases are escaping, and these may cause serious loss. The intensity of smoke has usually been measured by comparison with charts or cards having numbered and graduated shades printed on them. The best known of these is Ringleman's, which has five such shades, made by ruling black lines of different thicknesses at right angles to each other on white cards. The shades are obtained as follows:—

No. 1 has black lines 1 mm. thick and 9 mm. apart.
,, 2 ,, ,, 2·3 ,, ,, 7·7 ,,
,, 3 ,, ,, 3·7 ,, ,, 6·3 ,,
,, 4 ,, ,, 5·5 ,, ,, 4·5 ,,
,, 5 is all black.

The cards should be about 9 in. square, and placed about 50 or 60 ft. from the eye, and compared with the smoke issuing from the chimney; the lines and spaces give at this distance a grey effect. Such a method is crude, and, except for comparing the smoke from the same chimney at different times, or from chimneys of similar diameter, is of little use. The shade of the smoke depends as much on the thickness of the layer looked through as on its density. Any such method should, to be at all accurate, take account of the diameter of the chimney. The advisability of preventing smoke arises, not only from the loss of fuel involved in its production, as from its injurious effects on animal and vegetable life, as well as on buildings. Few plants thrive in smoky cities, the air of which is especially fatal to conifers; the plane tree is one of the few that can survive such conditions. The effect of smoke on buildings is due to the deposit of its solid matter, which not only disfigures them but acts as a vehicle for the sulphur acids evolved with the smoke; these attack limestone and iron-work, and rapidly destroy them.

Turning now to methods of prevention:

certain primary conditions must be fulfilled; these are:—

(1) Enough air must be supplied to combine with the carbon of the fuel.

(2) This air must be mixed intimately with the gases from the coal.

(3) The temperature of the gases must not fall below 700° C. until combustion is completed.

The undue cooling of the gases is probably the most potent cause of smoke, as it is more common to have too much air supplied than too little, and this reduces the temperature of the gases below the ignition point. Such cooling also results from the contact of flame with a cold surface, such as that of water-tubes or boiler-plates; hence it is important to provide in boiler furnaces a sufficient space for combustion to be completed before the flames come in contact with the comparatively cold surface of the boiler. This means the provision of a sufficiently large fire-brick-lined combustion chamber.

When we consider domestic fires, which are a source of a large proportion of smoke, we see that it is practically impossible to fulfil the above conditions. Too much air is admitted, the gases are cooled below their ignition points, and the flames come in contact with cold surfaces at many points. We may say, therefore, that no method has ever been devised which prevents the issue of smoke from domestic grates burning bituminous coal. The solution of the smoke problem lies in a different direction, and will doubtless be the burning of a smokeless fuel, either solid or gaseous. Of solid we have a choice of anthracite, coke, or partially coked coal; and of gaseous we have at present only coal-gas to consider. In a country where electricity can only be produced on a large scale by the combustion of coal we can hardly look to electric heating as a solution, owing to its cost. Domestic heating by means of ordinary coal or coke fires, anthracite burnt in specially constructed stoves, and gas fires, when the fires are run continuously, costs approximately as follows, based on tests in rooms of about 4,000 cub. ft. capacity:—Coal 0·026 to 0·033, coke 0·037, anthracite 0·01, and coal gas 0·11, in pence per hour per degree F. of rise in temperature of the room air.

It is probable that the solution of smokeless domestic heating will be eventually found in the production of some form of cheap gas at the coalfields, and its supply to our cities through high-pressure mains.

The case of large furnaces for steam raising is different, and these can be successfully operated with bituminous coal with a practical absence of smoke. It is chiefly a question of stoking, but the furnaces must be properly constructed and proportioned in the first instance, with ample grate area and combustion chamber. It has been found that while theoretically hand stoking can be so done as to practically prevent smoke, too much depends on the stoker, and mechanical appliances are more successful.

Mechanical stokers may be roughly divided into three classes:—

(1) Coking stokers. In these the coal is fed mechanically to the front part of the furnace, where the gases are distilled off; these are passed over the incandescent fuel at the back, and there burnt. As the gases are driven off, the coke left is pushed gradually towards the back of the furnace and there burnt.

(2) Sprinkling stokers. These act by scattering over the incandescent fuel in the furnace small quantities of fresh coal at regular intervals. The quantity being small is consumed with little or no smoke.

(3) Underfeed stokers. In this type the fuel is forced up from below at a regular rate into a specially constructed furnace. The gases distilled off are therefore forced to pass up through the incandescent fuel on the surface, and are thus consumed.

Smoke may be prevented also by forcing jets of heated air into the furnace near the back.

Turning now to the legal aspect of the question. The Public Health Act of 1875 contains the statutory law relating to smoke

emission throughout England, excepting London.

The Public Health Act (London) of 1891 includes the sections relating to smoke in the Act of 1875, making them applicable to the administrative county of London.

Both of these Acts make it an offence to emit from any chimney, not being the chimney of a private dwelling-house, "black smoke in such quantities as to be a nuisance."

It is curious to observe that there is probably no such thing as "black" coal smoke; it is usually of a brownish shade, hence the presence of the word black renders the application of the Act difficult. J. S. O.

Snow.—When the temperature of the air is about or below the freezing-point, precipitation usually takes the form of snow instead of rain. Snow-flakes are six-pointed crystals, and are of great variety. Scoresby, Glaisher, and others have made a large number of drawings of snow crystals; and during recent years photographs of snow-flakes under the microscope have been obtained, notably by Mr. W. A. Bentley, of Jericho, Vt., U. S. A. These all show the crystals to be of extreme beauty. When snow is falling, if any one will catch some of the flakes on the sleeve of his coat and look at them under a magnifying glass, he will be charmed by their exquisite beauty. Their size varies, but it is generally from one-tenth to three-tenths of an inch in diameter. Although snowflakes are so small, yet when they accumulate they often do a great deal of damage, especially if the wind is high and causes snow-drifts. These render traffic almost impossible, and often cause loss of life to both human beings and animals. Snow is measured by the rain-gauge; that which is collected in the funnel being melted and measured as rain. A foot of snow is roughly equal to an inch of rain. Snow, however, varies greatly in density; with very loose snow as much as 16 in. may only produce an inch of water, while at other times, especially in blizzards, snow may be granular, something like sand, and then 7 in. may produce an inch of water. W. M.

Soil Pipes. (*See* "PLUMBING.")

Sol.—A term introduced by Graham to denote the apparent solubility of colloidal matters (*q. v.*).

Sparge Pipe.—A pipe having fine holes drilled throughout its length so as to deliver a spray of water as is required for flushing.

Spence's "Alumino Ferric" (Treatment of Sewage).—Alumino-ferric and lime are used as precipitants at Chiswick, on the advice of Dr. Tidy, chemist. Seven grains of lime to the gallon and five grains of the alum in solution are incorporated with the sewage by agitation. After precipitation the tank effluent is filtered. To each hundredweight of wet sludge are added 14 lbs. of lime previous to pressing in filter presses. The sludge is burned in a "Horsfall" refuse destructor.

Sprinklers for Sewage Beds. (*See* "SEWAGE DISPOSAL" and "DISTRIBUTORS, FOR SEWAGE.")

Springs.—These are of two classes, "Land Springs" and "Deep Springs." The land springs rise from superficial beds of sand or gravel lying upon an impermeable stratum of clay or rock; consequently their flow is irregular, are immediately dependent on the rainfall, and are generally dry during summer. Deep springs are supplied from deep-seated water-bearing stratum, such as chalk, green-sand, &c. The water therefrom is usually free from organic and suspended matters, having filtered through considerable thicknesses of strata. Spring-water often contains dissolved inorganic matters taken up from the rocks through which it has percolated. The flow or yield of a deep spring, though variable, is more constant than that of land springs, and, generally speaking, the deeper the stratum from which the supply is obtained, the more regular the flow. Very commonly the yield is lowest in October or November,

and highest in the following February or March, but is dependent upon the rainfall.

Various conditions determine the amount of rain which percolates the ground: (1) nature of the soil; (2) configuration of the land; (3) temperature and movement of the air. Clay is almost impervious, gravel or a loose sandy soil absorb about 96 %, limestone about 20 %, chalk about 42 %. In a flat district evaporation may amount to 50 % less than in an undulating one. "Land" springs are derived from shallow beds of gravel, and their flow is uncertain. "Main springs" come from deeper strata; their yield is more constant, and usually of a better quality. Where springs afford the supply to a town, the "gathering grounds" require to be kept under close observation to detect any possible sources of pollution. As instances of good supplies from springs may be mentioned the chalk-water springs of Amwell and Chadwell in Hertfordshire, the supplies to Malvern and Tunbridge Wells. Some of the best spring waters are derived from granitic, jurassic and cretaceous strata. Spring and deep well waters form a favourable medium for the propagation of certain germs, and should, therefore, be carefully guarded against pollution in the course of delivery to the consumer.

Stable Construction and Sanitation.—The essential conditions in stable construction from a sanitary standpoint, as distinct from the architectural, are:—Lighting, ventilation, paving, and drainage. Ample light makes for health and cleanliness, and, as glass is cheap, windows and skylights may be freely used if so placed and arranged as not to create draughts. Where economy is a consideration the admission of light may be arranged for by the insertion of squares of rough plate-glass or of glass tiles in the roof. As regards ventilation, this is amply provided for during the day by the windows and doors, which latter it is usual to hang in halves, so that the upper half may be left open while the lower is closed. It is during the night and at other times at which stables are closed that ventilation must be chiefly arranged for. This is best done by inlets fixed under the mangers and louvred outlets in the roof, or near the ceilings where there are rooms above the stables. Stable paving must in all cases be impervious, and may consist of grooved bricks made for the purpose, or of blue bricks on edge grouted in cement, or of concrete, granolithic cement, and similar materials. It is desirable that such surfaces be provided with shallow channelling, on the one hand, to facilitate the draining away of moisture, and, on the other, to prevent horses or other animals from slipping. The floors should be laid to a slight fall towards a collecting channel or gulley in the centre or at the back of each stall, the latter being the more desirable. This fall should not exceed 1 in 40, as a steeper inclination causes discomfort to animals. The gradient named is quite sufficient for the object in view, if the floor is reasonably well laid. The collecting channels may be formed in the flooring itself with cement or blue bricks, &c., or they may take the form of cast-iron stable channelling having longitudinal slits in the cover which, while admitting liquids to the channels below, will exclude from them straw or other bedding materials. These covers should be removable in order that the channels may be occasionally swilled with water and brushed out. The channels should be carried through the wall to the exterior and arranged to discharge over gully traps, which in their turn may be connected to the general drainage scheme, or arranged to discharge into a properly-constructed tank in cases where it is desired to collect the liquid for manurial purposes. Channels in stables are preferable to collecting gullies, as the drains from these are not so readily kept clean as the channels. If used, the gullies should be provided with double gratings to exclude straw, &c., from the drains. The drains from them should also be arranged to discharge over gullies in the open, as the seals of the traps in the stables are liable to be destroyed by evaporation. As regards the walls, partitions, and the general

construction of stables, it may be said that all should be as smooth as possible so as to minimise possible lodgment for dust, dirt, and bacteria. For the same reason all angles and corners should be rounded. The walls and partitions should further be so constructed and decorated that they may be easily washed down. G. J. G. J.

Stand-pipes. (*See* "WATER SUPPLY" and "PUMPS AND PUMPING MACHINERY.")

Stand-pipe and Air-Vessel.—These are important accessories in connection with any system of pumping machinery, their function being to absorb the excess and to compensate

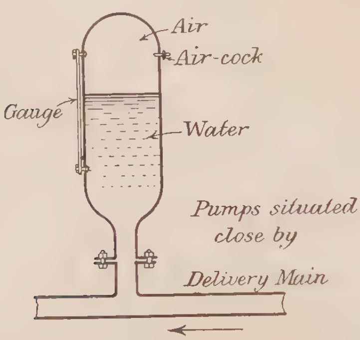


FIG. 1.—Cylindrical Air-vessel on Delivery Main.

for the deficiency of delivery by the pumps. Excess of delivery causes the water column in the stand-pipe to rise, and this falls again when needed to balance any deficiency of supply. The work thus expended in lifting the water column, or of forcing water into the air-vessel against the cushion of compressed air contained in the upper part of the dome, is given out again to the advancing water in the main and so equalises any weakness of pressure occurring therein.

The air-vessel also relieves the valves from severe shocks, and is of special use on high lifts and heavy pressures. Air vessels often enable pumps to be worked at increased speeds, and should be so arranged as to be readily recharged with air to replace absorption by the water.

In considering the size and shape of an air-vessel the degree of pressure and the ratio of excess of delivery of the pumps are the important factors to be kept in view. In practice the sizes vary, according to circumstances, from four to fourteen times, or more, the capacity of the barrel of the pump. Air-vessels are made proportionately larger when subjected to high pressures. To prevent the

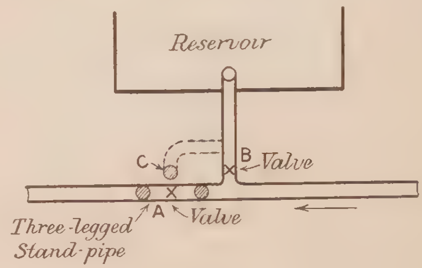


FIG. 2.—Three-legged Stand-pipe on Pumping Main

water being forced too high into the air-vessel and the rapid absorption of the air by the water, the vessel is usually made with a long narrow neck, as the larger the surface in contact with the water the quicker the absorption. Sometimes a disc of wood an inch or two smaller than the diameter of the air-vessel is placed on the top of the water in the vessel so

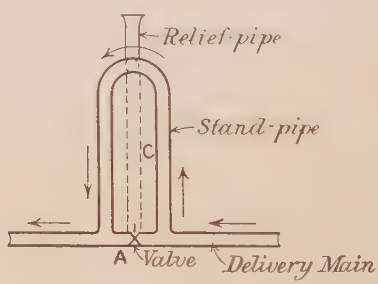


FIG. 3.—Elevation of Stand-pipe on Pumping Main.

as to reduce the surface in contact with the air. Provision must be made by means of a small air-pump, or by a "snifting-valve," for replenishing the air in the vessel thus gradually dissolved in the water. An air-vessel, to be most effective in the prevention of shocks due to the momentum of the water in the opening and closing of the valves, should be placed close to the pump on the delivery

main and connected up by a branch pipe of large diameter. Where a large mass of water is put into motion in the suction-pipe by each stroke of the pumps, it is advisable to provide the suction with a foot-valve and also to fix an air-vessel in the suction pipes to effect a more gradual arrest of the water and reduce the impact on the pump-valves. The balloon-shaped air-vessels retain the air longer than those of cylindrical shape. The vessels are made of cast-iron, should be of ample strength according to the pressure to be borne, and be provided with air-cocks at the top and draw-off cocks at the bottom to admit air or drain the rising main if required. In the United States it is the practice to employ huge cylindrical metal towers or tank stand-pipes which are frequently of sufficient capacity to serve as service reservoirs, and hold a full day's domestic consumption and several hours' fire consumption of water, or more. At Sandusky, Ohio, is a stand-pipe 25 ft. diameter and 229 ft. high. The diagram (Fig. 2) illustrates the application of a "stand-pipe" to a pumping or rising main, which is brought into use by closing the valves *A* and *B* when the water passes over the top of stand-pipe and gives the additional "head" gained by its height—any surplus water pumped passing down the third leg *C* and into the low service reservoir adjoining. The application of an "air-vessel" to an ordinary delivery or pumping main is shown diagrammatically in Fig. 3.

Steam-Engines.—In classifying steam-engines and machinery for waterworks and general pumping purposes, a great many independent characteristics in regard to their general arrangement of parts and methods of working must be taken into consideration. They may, for example, be divided into condensing and non-condensing, compound and non-compound, single and double-acting, geared and direct coupled, direct and crank-shaft, rotative and non-rotative, and vertical, horizontal, inclined, or inverted cylinder engines.

Non-condensing engines exhaust their steam direct into the atmosphere or into a receiver where the pressure is greater than that of the atmosphere. The steam is used at full pressure either partially or throughout the stroke, sufficient allowance being made to "cut off" and avoid back-pressure. Condensing engines exhaust their steam after forcing the piston from the beginning to the end of the stroke into a separate chamber termed a "condenser," which is maintained in a state of partial vacuum, the steam being therein condensed by contact with a nest of tubes through or around which cold water is constantly circulated (surface condensing), or, in some forms, a jet of cold water is sprayed into the condenser and meets the incoming steam (jet condensing). The condensed water and air are removed from the condenser by an air-pump usually worked from the engine, and the water, having a probable temperature of about 115° F., is used for feeding the boilers. The advantages of condensing are very considerable, and the process should be adopted in all but quite the smaller sized engines, as a great economy of steam consumption is effected thereby. Engines are classified as compound or non-compound according to the number of expansions of the steam obtained in the cylinders. The non-compound or simple engine consists of a single cylinder in which the steam does its work, and is then exhausted either directly into the atmosphere or into a condenser. In the compound engine the steam, after having partially expanded and done work in the small or high pressure cylinder, is exhausted into a larger or low-pressure cylinder, where it undergoes a further expansion before being exhausted into the condenser. In the triple and quadruple expansion engines the steam does work in three and four successive cylinders respectively before being finally exhausted into the condenser.

A single-acting engine is one in which the steam acts upon one side of the piston only. In a double-acting engine it acts upon both sides of the piston alternately. Both single

and double-acting engines are made either of the condensing or non-condensing type. Another important distinction in the classification of pumping engines and machinery lies between geared and direct-coupled machinery. In geared pumping machinery high speed engines are employed, and the pumps are driven therefrom by means of gearing, toothed wheels, or by means of belting, chains, or ropes. By these means the engine is usually run at a greater speed than the pumps, and some economy of steam consumption per indicated horse-power should be secured. Another advantage looked for in this system is that of less capital cost for the engine and lighter foundations. There will, on the other hand, usually be a lower mechanical efficiency (probably not more than from 65 to 75 °/₀), greater liability to break down, increased wear and tear, noise, and vibration.

In direct-coupled pumping machinery the pumps are connected to the steam ends, the number of reciprocations of the pumps is the same as in the engine, and the mechanical efficiency may be as high as 92 °/₀. There is less wear and tear, less liability to break down, and the vertical direct-acting type of machinery is usually the most satisfactory for large stations. A distinction is also to be noted between direct and crank-shaft with fly-wheel engines. In the direct engine the piston-rod of the engine and the piston-rod or plunger of the pump are continuous, there being no crank-shaft or fly-wheel. Roughly speaking it may be said that a typical direct-engine consists of two cylinders placed side by side, the admission of steam being controlled by ordinary three-ported slide valves. As the piston of one cylinder is moving towards the other end of the cylinder it strikes a lever actuating the slide valve of the other cylinder, and in this way each piston alternately actuates the slide valve admitting steam to the other cylinder. Frequently, however, one of the two cylinders named is simply a very small one, the function of which is to actuate the slide valve of the large cylinder. Engines of this class are quite self-acting, convenient, and compact, but are not economical, there being no expansion of the steam. Of later years, however, very great improvements have been made by "compounding" and by the introduction of "high-duty gear," the function of this latter improvement being to absorb a certain quantity of power at the beginning of the stroke and to give it off again towards the end—the steam working expansively in the cylinder. The most modern direct-engines embodying the latest improvements in the economical use of steam are thus amongst the most efficient pumping engines employed.

The "beam engine" is the earliest form of crank-shaft and fly-wheel engine, many examples of which are still in use, though this type is gradually being superseded. The advantage of the modern forms of crank-shaft pumping engines is that they lend themselves favourably to the expansive working of steam, and various ways are adopted in practice of arranging the cylinders and cranks in the compound and triple-expansion engines of this class. The best form is that in which there are three cylinders, each working a pump by means of a "three-throw" crank—the cranks being placed at angles of 120°. From such a pump the delivery of water is quite uniform, which is an important consideration, especially where the water is delivered direct into the distributing mains.

When the reciprocating motion of the piston of an engine does work simply upon a reciprocating piece the engine is termed non-rotative, but when the work is done upon a continuously revolving shaft, as is more generally the case, the engine is then of the rotative class. Usually the crank pin of the revolving shaft is connected directly with the piston-rod by a connecting-rod, and the engine is said to be direct-acting. Engines are also sometimes classified according to the position and arrangement of the cylinder, and are then described as horizontal, vertical, or inclined cylinder engines respectively. If the cylinder is above the connecting-rod and crank, as in many vertical engines, the engine is described as of the inverted cylinder class.

The duty or effective work of a pumping engine is expressed by stating the ratio of the product in foot-pounds of the weight of water raised into the height it has to be lifted with relation to 1 cwt. (112 lbs.) of coal consumed in lifting the water. In America 100 lbs. of coal is adopted as the unit of measurement, and some misunderstanding not infrequently arises by the comparison of results reduced to these different standards. In refined experiments the weight of ashes and clinkers is deducted and the unit of fuel taken on the combustible portion of the coal used. According to the dynamic theory of heat, 1 lb. of average good coal contains about 14,000 units of heat which are developed into a force capable of doing a definite amount of work when burned to produce steam. In actual practice a very large proportion of these heat units are lost in various ways, such as by escape up the chimney, by condensation of the steam in pipes and cylinders, by leakage past the piston or valves, and by escape with the exhaust steam into the condenser, so that in the end only some 10 or 12 % are usually transformed into actual useful work. Any successful efforts, therefore, to reduce these several sources of loss to a minimum will result in increased efficiency and economy of working. The efficiency of the steam-engine is represented by the ratio which the power developed in the cylinders (stated in thermal units) bears to the heat units supplied to the engine.

The mechanical efficiency of an engine is the inverse ratio which the I.H.P. bears to the power given off at the crank-shaft or fly-wheel (B.H.P.). The efficiency of the pump is the inverse ratio of the latter to the work done. The work done is stated in foot-pounds, and is represented by the product of the weight of water raised (in pounds) into the actual lift or head (in feet).

The steam-engine is a heat engine, and the true measure of its efficiency is the amount of heat consumed in the performance of a definite amount of useful work; but as the total units of heat in a pound of dry steam differs but little through the pressures commonly employed,[1] it is regarded as a sufficiently approximate and convenient means of comparing the efficiencies of engines to state the pounds of dry steam used in the cylinders to generate 1 h.p. of work. In good class engines the following results of steam consumption per horse-power hour are readily obtainable:—

	Per Hour.
Non-condensing engines .	25 lbs. steam per I.H.P.
Condensing ,, .	18 lbs. ,,
Compound ,, .	14 to 16 lbs. ,,
Triple-expansion ,, .	12 to 13 lbs. ,,

It will also be convenient here to state what may be considered good results in coal consumption per horse-power for various classes of engines:—

	Per Hour.
Non-condensing engines .	3 lbs. coal per I.H.P.
Condensing ,, .	2 lbs. ,,
Compound ,, .	$1\frac{1}{2}$ to $1\frac{3}{4}$ lbs. ,,
Triple-expansion ,, .	$1\frac{1}{4}$ to $1\frac{1}{2}$ lbs. ,,

A small coal consumption indicates an economical engine and boiler, but a large consumption does not necessarily prove the reverse, so that the rating of an engine according to the coal burned is not a reliable method, as many other questions are also involved, such, for example, as the quality of the coal and the manner of stoking. In any trials for efficiency it is necessary to distinguish that of the steam-engine from the efficiency of the boiler.

For further information *see also articles on* "CONDENSING," "INDICATOR," "STEAM RAISING," "ECONOMISERS," "HORSE-POWER," "BOILERS," "FUEL." W. H. M.

Steam Raising.—In modern economical steam raising various devices are employed with the object of producing steam with a minimum consumption of fuel by economising all waste heat as fully as possible, and of reducing the losses due to condensation of the steam during its use. Some of the

[1] At absolute pressure of 80 lbs. per square inch the total heat in 1 lb. of steam from water at 32° F. is 1,177 British thermal units; at 150 lbs. pressure it is 1,191·2 units.

methods employed are, the use of superheated steam, of economisers or feed-water heaters, steam dryers and purifiers, and steam jacketing.

Superheated Steam.—Steam formed in an open boiler under atmospheric pressure (14·7 lbs. per square inch) has the same temperature as the boiling water, 212° F. When the boiler is closed, as with a weighted valve, steam is formed at a higher temperature, because of the greater pressure. The vapour of water boiled in a partial vacuum will have a temperature below 212° because of the lower pressure. Steam formed in contact with water, as in an ordinary boiler, and containing watery particles is called wet saturated steam. When all the water has just boiled away and the saturation point is reached—all the latent heat required for the steam having been taken up—we have dry saturated steam. Saturated steam, which is perfectly dry, contains in a given volume, and at a given temperature, the maximum weight of evaporated water, and has the maxima pressure and density attainable at such temperature. Dry saturated steam is only approximated to in practice by providing domes to boilers in order to remove the steam as far as possible from the water. Applying heat still further, after having removed the steam from the presence of water, it becomes surcharged with heat, and is then said to be superheated steam, that is, steam which has its temperature raised above formation point. The more it is heated the more nearly will its properties approach those of a perfect gas. Superheated steam cannot exist in the presence of water, as the latter will absorb the surplus of superheat and the steam thus reverts to the saturated state. The advantages to be derived from the use of superheated steam are the prevention of condensation and consequent fall in steam pressure in passing from the boiler to the engine, and, in the engine, the elimination of condensation losses within the cylinder due to exchange of heat between the steam and metal cylinder walls. The object to be achieved therefore is to deliver the steam into the cylinder with such surplus heat as will prevent condensation, thus keeping the steam as dry as possible throughout the stroke. The advantages of superheating were demonstrated by Hirn as long ago as 1855, but troubles were experienced at the superheater, and the cylinder lubricants were burned up, resulting in the abandonment of the process in 1870. Upon the introduction of safer superheaters and heavy mineral lubricating oils the original objections were removed, and a revival of superheating has taken place since 1890, producing an important improvement in the thermodynamic economy of engines. The gain from superheating may be taken at an average of about 25°/₀, but varies from 10 to 50°/₀ with 50° to 100° of superheat according to the efficiency of the engine. Mr. M. Longridge has given it as his opinion that 400° F. of superheat in the cylinder is sufficient to prevent initial condensation, and that the superheater, to be efficient, should have a head of about 400° F. above the temperature of the superheated steam. In practice, the steam to be superheated is led off from the boiler into a separate vessel or accessory appliance called a "superheater," and in which it is subjected to the additional heat. Superheaters are either of the flue-fired class or are independently-fired. Flue-fired superheaters are placed in the down-takes of Lancashire and Cornish boilers, where they are heated by the gases from the furnace flues, thus utilising what would otherwise pass away as waste heat. With boilers of the water-tube class independently-fired superheaters are mostly used. Some highly economical results, not obtainable from steam in any other way, have been obtained by Mr. Schmidt, whose experiments have shown it possible to employ steam superheated by as much as 300° F. In trials of the Schmidt engine and superheater, the consumption of steam has been well below 10 lbs. per Indicated H.P. hour, and the consumption of coal in boiler and superheater together, it was found, was as low as 1·3 lb. per Indicated H.P. even with small engines. In these trials, after the hot gases had passed the superheater, as much of the remaining heat was utilised as possible

in an economiser or feed water-heater for the interception and return of the heat to the boiler.

STEAM: EQUIVALENT WEIGHT OF WATER AS EVAPORATED FROM AND AT 212° F.—For the purpose of comparing evaporative boiler tests, the results obtained must be reduced to a common standard, which is usually reckoned from and at 212° F. The method of calculating these results will be best understood by the following example:—

From the tests made, suppose that 1 lb. of the coal used has been found to evaporate 9·71 lbs. of water, with boiler feed at 145° F. and steam pressure 90 lbs. per square inch, as shown by the gauge. Steam at 90 lbs. gauge pressure is equivalent to 90 + 15 lbs. (atmospheric pressure), that is, 105 lbs. absolute. By reference to Regnault's tables of the properties of saturated steam (to be found in the majority of engineering pocket-books), it will be seen that the temperature of steam at 105 lbs. absolute is 331·3° F., and also that the total heat in 1 lb. of steam at that pressure from water at 32° F. is 1,183 British thermal units.

The latent heat in 1 lb. of steam at 212° F. is 966·6 British thermal units (see tables), and the equivalent weight of water evaporated per pound of coal from and at 212° F. is therefore represented by the following equation:—

$$W = \frac{H - (t - 32°)}{966·6} \times w,$$

in which,—

W = the equivalent weight of water evaporated from and at 212° F.;

H = total heat of steam (in British thermal units) at the temperature corresponding to the pressure, from water at 32° F.;

t = temperature of boiler feed during the test;

w = weight of water actually evaporated per pound of coal from temperature (t) of feed.

Substituting the numerical values in the above example, we have—

$$W = \frac{1183 - (145 - 32)}{966·6} \times 9·71$$

$$\therefore W = \frac{1070}{966·6} \times 9·71 = 10·748 \text{ lbs.}$$

Sterilisation of Water can be effected by (1) heat, (2) filtration, (3) certain chemical agents.

(1) HEAT.—Boiling is an efficient means on a small scale, but the expense is prohibitive when large quantities have to be regularly dealt with, and the resultant liquid is deaërated and less palatable. In the Rouart, Geneste-Herscher, and Vaillard-Desmaroux sterilisers the water is heated for a short time to 113-116° C. in a closed vessel, or a system of coils, whereby the outgoing is made to heat the incoming water, at the same time being itself cooled to near the ordinary temperature. In this way the natural gases are retained, very little earthy deposit occurs, and the sterilised water is protected from air. A deposit, however, does accumulate, and the narrow coils sometimes block, and are difficult to clean. In the Forbes apparatus, used in the United States army, the water is only boiled for a few seconds, so that it preserves most of its original gas and taste; it then passes over a weir into a temperature exchanger. The working is regulated by a valve. Other types used in America are the Kny-Scheerer, Maignen, and Von Siemens. In England the Lawrence steriliser and softener has been in use for some time at Guy's Hospital and elsewhere. Its boiler is a vertical cylinder fitted with depositing trays above the water line and plates called "locators" below it. The water boils up over the trays and deposits its lime and magnesia carbonates on the trays and locators (which are removable for renewal or cleaning), and passes to an interchanger. The writer's results with different heat sterilisers showed that sterility, even with very varying rates of flow, can with care be insured.

FILTRATION.—Sand and mechanical filters in good condition, and under favourable circumstances, yield a sterile effluent, but such a result can only be depended upon with a much finer medium. The only filter that has stood all tests is the Pasteur-Chamberland "candle" filter of biscuit porcelain, in which the water passes from the outside inwards, under pressure from the main, a force pump, or exhaust.

The tube is very carefully cleaned, and should be sterilised by boiling at intervals. The average yield per tube is estimated at ½ gallon per day with only an ordinary head of water, and 8 gallons per day with pressure. The tubes can be arranged in "batteries" of any number, and the joints must be carefully attended to.

Chemical Agents.—For chlorine, ozone, and permanganate, see respective articles and "Condy's Fluid." It has long been known that acids generally, and many metallic salts, are antagonistic to bacteria, but for sterilisation of ordinary water an agent is required which is not costly and is non-poisonous to higher life, and this limits the application to special cases.

0·072 °/₀ of sulphuric acid is effective against *B. typhosus* in 15 minutes, and 62 grains per gallon is sufficient to destroy typhoid organisms in the usual drainage from an isolation hospital or other infected area. *B. enteritidis Sp. choleræ*, intestinal worms and ova,[1] are also killed, and the free acidity is soon neutralised on mixture with ordinary sewage. For sterilising water in campaigns bisulphate of soda, 15 grains per pint, is portable and effective.[2]

With the same object Schumberg in the German army has used bromine, 6 parts per 100,000, followed by a tablet of sodium sulphite and mannite, but among the objections have been the difficulty of transporting the bromine, and the presence of bromides in the water.[3] Allain at Marseilles used iodine, and Nesfield in India has employed a tablet containing iodide and iodate and another containing tartaric or citric acid; together, when used as directed, they liberate 5 parts of iodine per 100,000 of water; after 2 to 5 minutes any excess of iodine is removed by a tablet of sodium sulphite. The writer found that the sterilisation was satisfactory.[4] (*See* "Algæ in Water Supplies"; "Filters, Domestic"; "Filtration"; "Water Supply, Domestic.")

Copper salts in small quantities have been repeatedly tried. One in 8,500 of the sulphate, or 1 in 13,500 of the chloride, kills *B. coli* in 3 hours; 1 in 7,000 of sulphate, or 1 in 10,000 of chloride, kills *Staph. aureus* in 2 hours. One in 1 to 10,000,000 prevents the growth of algæ, and in this small quantity it is not poisonous to man or to fish, and is removed after a time by natural precipitation.[1]

S. R.

[1] Valerio, "Bull. Soc. Vaudoise Sci. Nat.," 1902, No. 143.

[2] Parkes and Rideal, "Epidem. Soc.," 1901; *Lancet*, Jan. 26th, 1901.

[3] *Public Health*, Sept., 1902, p. 709.

[4] *J. of Prevent. Medicine*, Oct., 1905; *Indian Med. Gaz.*, Aug., 1905.

Storm-water.—The quantity of storm-water or dilute sewage coming down to the outfall works during rainy periods is a very variable quantity in different districts. The proportion of the total rainfall reaching the sewers depends largely upon the character of the district; obviously, a much greater flow would be experienced from a hilly area with a clay or other impervious soil than would be derived from a flat chalky or other porous and absorbent area. The extent to which the district is built upon, and the proportion of paved areas, also influences the total of storm-water to be provided for. Another feature is the condition of soundness, or otherwise, of the sewers and the consequent extent to which subsoil water may be able to gain access thereto. Where the sewers are old, leaky, of porous or defective brickwork, and such like, the amount of subsoil water draining away through them may easily be far in excess of the sewage proper. The ordinary dry weather flow of sewage should closely approximate to the amount of the water supply of the district. This may be anything from about 25 gallons to 35 gallons per head per day. All sewage flow beyond this amount would, therefore, be due to rainfall or subsoil soakage, and, to a less extent, in some cases to manufacturers' wastes, in so far as the water supply for such

[1] "Bulletin U.S. Department of Agriculture," 1903; "Zeits. f. Hyg.," 1903, p. 495; *J. R. San. Inst.*, 1904, p. 591; *ibid.*, 1906, p. 556; *J. Prevent. Med.*, July, 1904; "Chem. Centralblatt," 1900, ii., 203.

trades was derived otherwise than from the town supply. In a very hilly district the storm-water is more difficult to cope with than in one of a less undulating character, because in the former case the storm-flow is relatively larger and reaches the outfall works much more suddenly. In other words, the rate of flow is more rapid, though of possibly shorter duration, and the provision to be made for the reception of such abnormal discharges must be relatively larger and more complete than in cases where the delivery is less violent.

One inch of rainfall in an hour occurs but seldom in this country, as in the case of exceptionally severe storms, so that a provision of sewer capacity to remove that amount should be ample. In fact, to further increase the sizes of sewers beyond this limit would seriously decrease their efficiency under ordinary working conditions, besides greatly enhancing the cost of sewering the district without any proportionate advantage. The London sewers were designed to remove only ·01 in. of rainfall per hour in addition to an allowance of 5 cu. ft. of sewage per head per day. It was estimated that only five-eighths of this rainfall would reach the sewers—the remaining three-eighths being evaporated or absorbed. Experience has shown that this allowance is too small. The sewerage system for Edinburgh gives provision for 42 gallons per head per day, one-half of this to flow off in 8 hours. Only in exceptional cases would the flow exceed 50 gallons per head per day. In some districts small natural streams find their way into the sewers, and these in rainy periods become quickly swollen, so that the ordinary calculations of the volume of storm-water to be dealt with are not applicable to such cases. There is no doubt that the first flush of storm-water delivered at the outfall is very foul and heavily laden with suspended matter, especially where the main sewers are in a defective condition. Storm overflows or reliefs should therefore not come into action until the rate of flow has increased to several times the normal. The provision of such "reliefs" or overflows is an essential part of the sewerage system. In a hilly district their absence might readily lead to the bursting of a main sewer owing to the volume of water coming down from the higher parts of the district heading up for the want of a free outlet, and so unduly increasing the pressure within the sewer. The flooding of premises in the lower parts along the line of sewer would also result.

There is a difficulty in fixing storm overflows to pass sewage at any fixed or uniform degree of dilution because the ordinary flow in sewers varies throughout the 24 hours—the sewage coming down during the morning hours, say 8 a.m. to 12 noon, is many times greater than the night flow from, say, 8 p.m. to 6 a.m., so that if the overflow is fixed for a dilution of six times the morning-flow, the night-flow, owing to its smaller volume, will necessarily be diluted to a much larger extent before any liquid passes the storm-overflow, and, as a result, the purification works will be saddled with a larger quantity of weak sewage during the night than is necessary. Purification works are much relieved by the provision of separate sewers for storm-water, as distinct from soil sewers, but in cases where the sewage is discharged into the sea a combined system will be most economical. Dr. Houston, the expert bacteriologist engaged by the Royal Commission on Sewage Disposal, upon investigations in this connection regards storm-waters as being "as potentially dangerous to health as normal crude sewage," but recognises the impracticability of treating the whole flow during storms. Where sewage farms are in use for dealing with the sewage an ample area of pasture land should be specially reserved for the overflow of storm-water. Such storm-water areas should not be used for taking part of the ordinary flow of sewage, but should, as far as possible, be reserved in a condition of readiness to receive large volumes of dilute sewage for short periods. The treatment should be one of surface irrigation without under-drainage.

Where land is not available, it has been the

practice of late years to provide special storm-water filters which act as mechanical strainers of the suspended matters from storm-waters and pass the liquid at the rate of about 500 gallons per square yard per day. These have frequently been simple excavations in the earth, filled with gravel, broken stone or clinker, but they have not, generally speaking, proved very satisfactory, and, on the whole, do not justify their cost. The money spent in the construction of storm-water beds would, in most cases, be more advantageously used in the provision of larger permanent filters upon which the ordinary flow of sewage is treated. By this means the whole area of beds may be kept in a mature and working condition, and a better average effluent produced, as the filtration can be done at a slower rate per volume of material. Special storm-filters, on the other hand, lie idle for long periods, and the money spent on their construction is thus not continually employed to the best advantage. The filters, too, become dry, and their oxidising efficiency is much impaired.

The Royal Commission on Sewage Disposal (fifth report, 1908) report unfavourably upon storm-filters, to the effect that they "are not usually efficient and should not be provided," but that the ordinary dry weather flow beds should be increased by $1\frac{1}{2}$ times so as to allow of the filtration of three times the mean dry weather flow by working at a permissible increased rate during storms. The Commissioners think it is practicable to filter this quantity—viz., three times the mean dry weather flow—and they doubt whether, as a general rule, the filtration of any larger amount will be found to be necessary to prevent nuisance.

Dealing with the past practice of the Local Government Board in the matter of storm-water, the Commissioners observe that "the usual requirements of the Local Government Board in regard to the treatment of storm-sewage are that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm-filters. These requirements should, we think, be modified; they are, in our opinion, not sufficiently elastic, and, moreover, experience has shown that special storm-filters, which are kept as stand-by filters, are not efficient. We find that the injury done to rivers by the discharge into them of large volumes of storm-sewage chiefly arises from the excessive amount of suspended solids which such sewage contains, and that these solids can be very rapidly removed by settlement. We therefore recommend, as a general rule, that—(1) Special stand-by tanks (two or more) should be provided at the works and kept empty for the purpose of receiving the excess of storm-water which cannot properly be passed through the ordinary tanks. As regards the amount which may be properly passed through the ordinary tanks, experience shows that in storm times the rate of flow through these tanks may usually be increased up to about three times the normal dry weather rate without serious disadvantage; (2) Any over-flow at the works should only be made from these special tanks, and this overflow should be arranged so that it will not come into operation until the tanks are full; (3) No special storm-filters should be provided, but that the ordinary filters should be enlarged to the extent necessary to provide for the filtration of the whole of the sewage, which, according to the circumstances of the particular place, requires treatment by filters."

W. H. M.

Street Cleansing.—Necessity and Objects—Orderly System—Mechanical Sweepers—Disposal of Refuse—Removal of Snow.

Necessity and Objects.—It is important, in order to maintain a high standard of public health, that the streets of all towns be cleansed. Wet and muddy streets cause dampness in the subsoil, and the moisture arising therefrom contaminates the atmosphere. Over-dry streets and roadways wear

badly, the surface becomes covered with gritty particles, and detritus is soon ground up by the traffic into fine dust, which is easily blown about, and becomes injurious to tradesmen's goods and to the public health. The existence of mud increases the difficulty of traction, renders the surfaces of pavements and roads slippery and dangerous, especially when paved with wood and asphalte. These materials become exceedingly slippery when covered by a thin greasy film of mud, but if kept clean, even though wet, are safe to travel on. It is therefore necessary to keep streets clean for sanitary reasons, for safety to traffic, for personal comfort, and also for the sake of appearance. Colonel Haywood ascertained the respective quantities of dust arising from the worn road surface of a granite pavement, and the amount of detritus collected each day. The wear which took place on 3-in. Aberdeen Granite setts in 9 years over an area of 3,950 super. yds. was equal to 2 in. measured vertically. This amounted to $219\frac{2}{5}$ cu. yds., and in the state of fine powder would probably amount to about one-tenth of a cubic yard per day. The amount of detritus, however, removed daily in fine weather was 30 times that quantity, thus illustrating the necessity of cleansing paved as well as macadam surfaces. Paved surfaces produce much less dust from ground-up materials, as compared with macadam, but they require frequent cleansing to keep them from becoming slippery and unsightly, and the difference in cost is not so great as might at first sight appear, but in times of frost, falls of snow, or wet weather, there is a decided saving in the cleansing of paved roads.

To ensure success in street cleansing well organised plans must be thought out so as to systematically cleanse all the streets in the district within reasonable spaces of time. Gangs of men should be so arranged that the main roads are swept first and the side roads after. To these gangs separate and distinct districts should be given and the work so arranged that all streets within each district are cleansed at least once a week. The first part of the work (viz., cleansing main streets) should be commenced in the early morning by the mechanical broom, if the surfaces and weather are suitable for its use. After this has swept the detritus to the sides of the roads, small gangs of from four men to six men should follow up with hand-brooms, shovels and carts, and pick up this detritus and cart it away to the slop shoot. Main streets through busy towns should be cleansed at least once a day, and all the work on them (except the removal of horse-droppings) done by 6 A.M.

ORDERLY SYSTEM.—This is a system in which men or boys remove the horse-droppings and other detritus on the surface at once. They are provided with either small scoops and short-handled brushes only, or with orderly trucks and the scoop and brush. In the former case, the droppings, &c., collected are deposited into orderly bins placed at the side of the road, and which are emptied at night-time. These bins are now being replaced in several towns by collecting pits sunk beneath the footpath, close to the kerbs, and covered over by hinged doors. Openings are left in the side facing the channel through which the droppings are pushed. These pits are emptied at night and can then be used as store places for orderly barrows, brooms, scrapers and squeegees. In some cities and towns the orderly boys place the refuse removed from the roads into bags provided for that purpose, and which are suspended from hooks on the side of a hand-cart. This is the system adopted in Paris, where the bags are usually placed inside a light wrought-iron hand-cart, some, however, being suspended on the outside in certain cases. The bag system saves considerable time in the collection of the refuse, and the offensive process of emptying the orderly bins or pits is done away with. The bags used should be of thick canvas and be made with iron framed lips, and with handles for carrying or hanging on to the hooks on the hand-carts. In Paris a large number of women and boys, as well as men, are employed in street cleansing. They commence from 3 A.M. to 4 A.M., according to the season of the year, and finish an hour before midday.

In the city of London principally men and boys are employed in this work. The men cleansers commence work at 8 P.M. and continue through the night until morning, and the orderly boys commence work an hour before the scavengers leave work, and continue during the day. The system by which men are employed in the early part of the night from 9 P.M. to 1 A.M., or 5 A.M. to 9 A.M. in the main thoroughfares, and the adoption of boys during the day-time, should work well in provincial towns. The men who cease work on the main thoroughfares will continue during the day cleansing the minor streets and other places.

MECHANICAL SWEEPERS.—These were first introduced by Sir Joseph Whitworth. There are many makes of these upon the market. The general principle is to attach a series of broad brooms of varying width (about 30 in.) to endless chains turning upon pulleys attached to a wrought-iron frame, the whole apparatus being attached to the back of a cart, having its body near the ground. The pulleys are attached to the cart-wheels and revolve with them. The sweepings are carried up an inclined plate and drop into the body of the cart. The brooms can be raised or lowered by hand. Haulage can be accomplished either by horse or motor-power. When the mud is in a stiff condition, a water-cart should precede the sweeper to convert the mud into slop, when it can easily be swept up. The brushes last about 180 hours, and it is estimated that the machine is equal to the work of 10 men.

DISPOSAL OF REFUSE.—Many methods are adopted for the disposal of street sweepings. The slop, after being removed from the streets, is carted to waste lands or special slop shoots where quarries or disused pits are to be filled up. Street sweepings and horse-droppings are sold or given to farmers as manure. On no account should road sweepings be sent to building sites for making up uneven surfaces. Epidemics of disease are liable to be caused by this system. Where cost will permit, the best method undoubtedly is to burn all street sweepings (with the exception of horse-droppings, which can often be disposed of for manure) as soon as possible after collection. If this is impracticable, H. P. Bulnois, in the "Municipal and Sanitary Engineers' Handbook," suggests that where possible they should be taken out and dropped into the sea in large hopper barges and sunk in deep water. It may, however, be possible to wash them at a small cost, and they can then be used as a matrix for mortar.

REMOVAL OF SNOW.—This is always a difficult and costly matter. Snow should not be removed while the fall continues, but directly it ceases, all available men and carts should be employed. Snow-ploughs are used for clearing the roadways, these being usually constructed of wood, and loaded when in use by being filled with snow or stones. Two or more rough-shod horses are required to draw an ordinary plough, and great care must be taken in using it that damage to the road surface is prevented. Sand should be sprinkled on the roads and footpaths to prevent slipperiness in frosty weather and after the removal of snow. Receptacles containing sand or fine gravel for sprinkling by hand labour should be placed at convenient intervals along the streets, especially in those paved with wood or asphalte. Space should be first cleared in the main thoroughfares, to allow of a double line of traffic, the snow being heaped in ridges at the sides of the road, and openings cut at frequent intervals for pedestrian traffic. The channels should be left clear in the case of a sudden thaw. Salt has been used of recent years to assist in the removal of snow from the carriage-ways, with good results. It should be spread as soon as any considerable amount of snow has fallen, as the traffic hastens the melting process. The slush formed can be easily swept to the sides of the road by the machine-broom and carted away, water-carts following up this process to wash the remaining slush and mixture off the surface. Salt has no detrimental effect on wood, granite, or asphalte carriage-ways, but causes considerable damage to macadamised carriage-ways, owing to the quantity of mud formed.

The amount of salt necessary depends entirely upon the conditions and amount of traffic. Foot-paths should be cleared as rapidly as possible, salt being used for this purpose. The slush formed by the salt should be removed very quickly owing to the great danger to the health of the public, caused by the lowered temperature. The snow should be shovelled into carts and deposited upon waste land and left to thaw. The system of tipping the snow down the manholes into the sewers is adopted in many towns, but care must be taken that the snow does not block up the sewer, as it takes a considerable time to melt. Where a town is near a river the snow should be tipped into it.

F. L. & R. H. B.

Streets. (*See* "Roads and Streets.")

Subsoil Drainage.—Extensive drainage of land renders the climate drier and more healthy by lowering the level of subsoil water and removing the miasmatic or malarial influences which accompany low-lying clay and water-logged, or marshy, soils. The land itself is rendered more pervious to the action of the air, so that the oxidation of waste products occurs more readily and germination is promoted, making bogs and marshes available for cultivation. The flow of the rivers is improved because the water formerly left to soak through the land is carried at once to the rivers either by gravitation or pumping. The fen lands of Huntingdonshire, Cambridgeshire, Lincolnshire, and elsewhere, have by draining been made habitable and healthy, and many thousands of acres have been brought into cultivation. The natural drainage of land is by means of ridge-furrows,

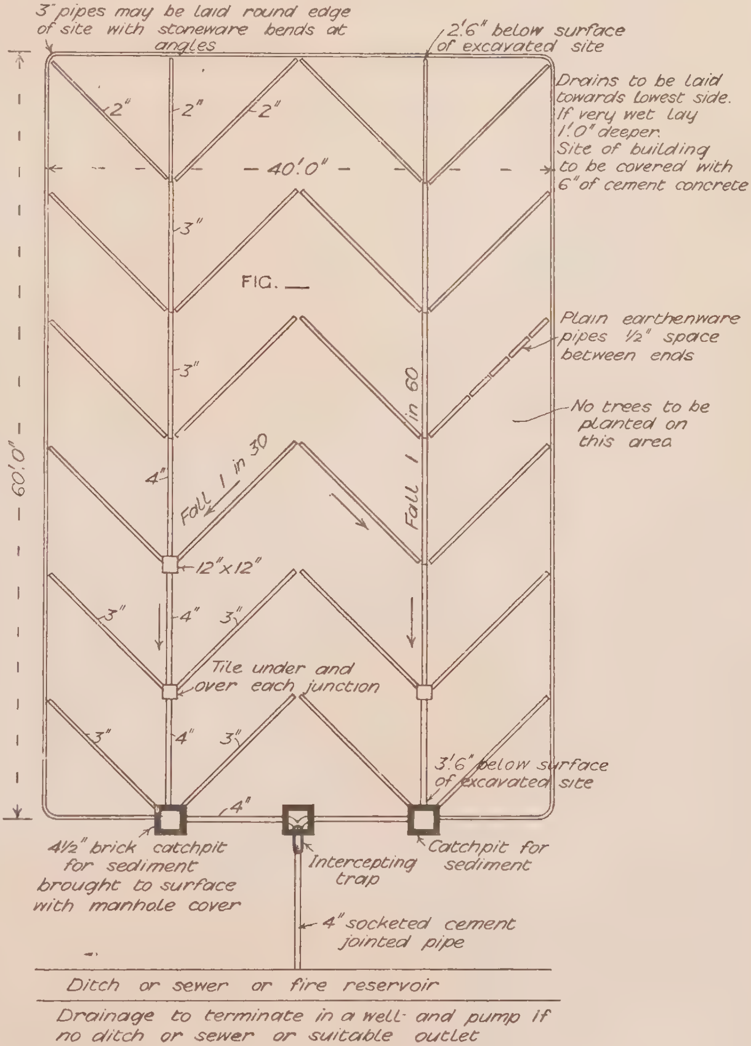


Fig. 1.—Plan of Drains.

ditches, watercourses, streams and rivers; this is effective for ordinary soils and circumstances, but in certain situations pipe-draining is necessary. Shallow drains for clay soils consist of 2 in. field pipes, from 18 in. to 2 ft. deep, and 10 to 20 ft. apart, laid with the fall of the land, or about 1 in 150, to the

nearest ditch or watercourse, or to dry steined wells or to "soak-aways" if there is no natural outlet. A soak-away is a square pit sunk in the ground and filled with rubble or brick-bats to admit water freely and let it

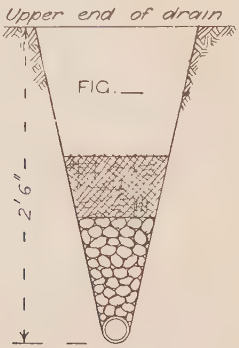


FIG. 2.—Section through Upper End of Drain.

soak away gradually. For light and porous soils deep drains are desirable, say from 3 in. to 4 in. diameter, 3 ft. 6 in. to 6 ft. deep and half a chain to a chain (33 ft. to 66 ft.) apart.

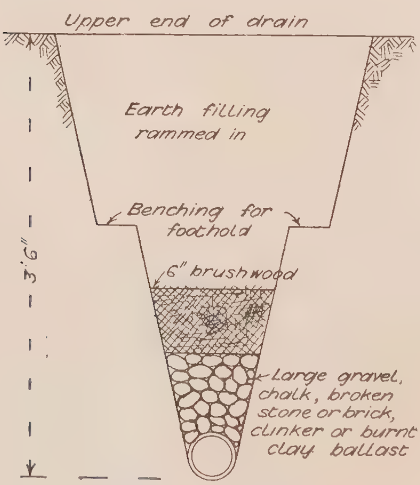


FIG. 3.—Section through Lower End of Drain.

In the heavy lands of Norfolk the drains which answer best are 2½ ft. deep and one-third of a chain (22 ft.) apart. Land planted with trees can only be drained by open cuts, as the roots would inevitably choke pipe drains. Drain pipes should not be less than 20 ft. away from growing timber. When a house has to be erected on a wet site the subsoil should be drained by agricultural pipes covered with brushwood or rubble to prevent the clogging of the pipes by the soil being carried down. Fig. 1 shows the plan of such drains, Fig. 2 section through the upper end

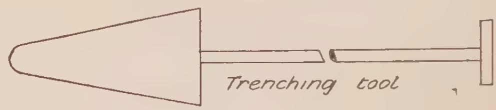


FIG. 4.—Trenching Tool.

of drain, Fig. 3 section through lower end of drain, Fig. 4 a trenching tool or spade, Fig. 5 a bent iron rod for laying the pipes in position. In open country, if the ground falls towards the house and brings down much water, a deep trench or ditch about 10 yds. away from it on the upper side will intercept

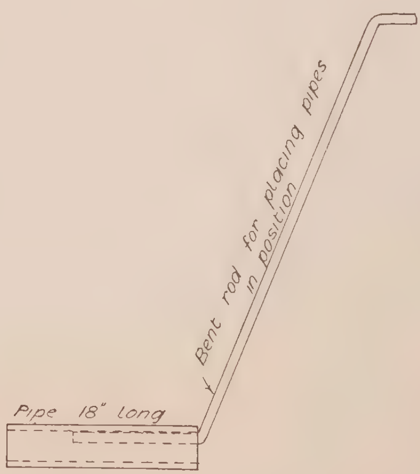


FIG. 5.—Iron Rod for Laying Pipes.

much of the water, and the cutting may if desired be filled in as a rubble drain or pipe drain with a deeper soak-away at each end. Where it is practicable it is often better to make the ditch or trench all round the house so as to draw away the moisture from beneath the footings and leave the foundation soil undisturbed.

H. A.

Suction of Pumps.—In the installation of a pumping plant every effort should be made to keep the suction of the pump as short as possible. All pumps work most smoothly with the water almost gravitating into the pump. The weight of the atmosphere (14·7 lbs. to the square inch) will balance a column of water 34 ft. in height, but in order to attain this depth of suction the pump must be absolutely perfect and capable of maintaining a complete vacuum. Such conditions are impossible to attain in practice, and, as mentioned above, the shorter the suction lift the better will be the working of the pump. Too long a suction is a frequent cause of trouble in the working of pumping machinery. It often happens that such a pump will not fill, and, upon the return stroke, the piston meets the rising column of water with a violent blow liable to cause considerable damage. Long suctions are especially unsuited for high-speed pumps, and it may be taken as a rule that the greater the speed of the pump, the shorter should be the suction. Horizontal length of suction is not so detrimental to the action of a pump as is excess of vertical height, but it should be avoided as far as possible, as it greatly increases the weight of water to be set in motion and stopped at each stroke, or at any rate alternately accelerated and retarded. With a vertical engine the arrangement of the suction is conveniently managed, as in this case the pumps are usually fixed below the engine-room floor level and within easy reach of the water to be raised. Corresponding facilities do not apply in the case of the horizontal type of engine. "Three-throw" pumps, as conveniently worked from a crank-shaft of a triple-cylinder engine, have the advantage that the flow of water in the suction, and also of course in the delivery pipes, is more uniformly maintained than in other forms. All suction pipes should be as straight as possible, any unavoidable bends being made of large radius; the suction should also be perfectly air-tight, and be provided with foot or retaining valves, especially in long suctions or heavy lifts, so as to keep the pump ready charged with water. The suction must be of larger diameter than the delivery, and additional diameter allowed if of great length. Strainers, with ample area of strainer-holes, should be fitted at the end of the suction to exclude foreign matters. At any unavoidable bends or possible air lodges in the suction pipe, air-cocks should be provided for the purpose of discharging the air and preventing "air-locking." W. H. M.

Surface Traps. ("*See* GULLIES.")

Surveying, General Principles of.—Chain Surveying—Angle Measuring Instruments — Theodolite — Ordnance Survey.—The fundamental process of surveying consists in setting out upon the area to be mapped a series of lines to form a basis of measurement.

CHAIN SURVEYING.—In "chain" surveying, all the lines are measured, and as the angles of a three-sided figure can be determined if the sides are known, angle measuring instruments are not essential, although it is often convenient to employ the simpler forms. A simple survey of open accessible country can usually be made with a chain, a tape, 10 arrows, 1 doz. ranging poles, some pegs, &c., and a "field-book" in which to enter the measurements and sketches taken on the ground. Extensive and more complicated surveys are carried out upon the trigonometrical principle that if the length of one side of a triangle and the angles included between this side and the others are known, the lengths of the remaining sides may be calculated. To conduct a "trigonometrical" survey a theodolite for measuring the angles will be required in addition to the apparatus used in chain surveying. The chain (Gunter's) generally used in surveying is composed of 100 steel wire links, each measuring 7·92 in. from centre to centre; the total length (including the handles) is, therefore, 66 ft. As the statute acre contains 10 square chains, calculations of area are simplified by adopting a chain of this length and division. In some

cases, however, such as for town work and levelling, a chain with 100 divisions of a foot is more convenient. The tape is of linen or steel; one side is divided into links, the other into feet and inches; a usual length is 66 ft. Before commencing each day's work both chain and tape should be tested between

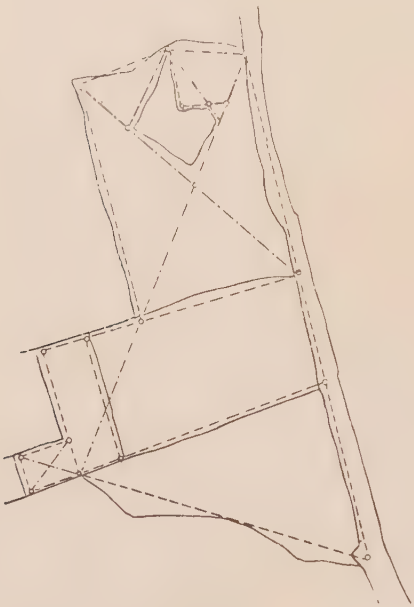


Fig. 1.

gauge marks set out upon a level surface; this is imperative when the survey is being made for legal purposes. Arrows are merely stout steel skewers about 15 in. long, with a small piece of red cloth attached to each to render them easily distinguishable; they are used to temporarily mark the number of chain lengths. The ranging poles are from 6 ft. to 10 ft. long, and are painted in alternate bands of black or red and white; they are shod with steel, and sometimes have small flags tied to them. A 10-link "offset staff" is often used for taking measurements on either side of the chain, but it is not indispensable, as this can be done with a ranging pole. The field-book is about 8 in. by 4 in. and opens lengthwise; each page is divided in the direction of its length by a central line (sometimes two parallel lines) which represents the chain line; upon it the distances on the chain are recorded and also the points at which offsets are taken, roads crossed, &c. To either side of this line (or lines) the distances to objects on the right or left of the chain line ("offsets") are entered and sketches made of fences, buildings, &c., together with any other notes that may be required. Each chain line is started from the bottom of a fresh page, working from the end of the book. At the commencement of a survey a reconnoitre of the ground is made and the principal lines ranged out with the poles. These lines should lie as near boundaries and other main features as possible in order that the offsets may not exceed about 50 links. Besides these lines, others, known as "proof" or "tie" lines, must be established as a check. The survey lines thus set out should be marked on a rough plan. The ends of the lines and their junctions with others constitute "stations"; the latter are marked on the ground with pegs or poles, and in the field-book by a small oval.

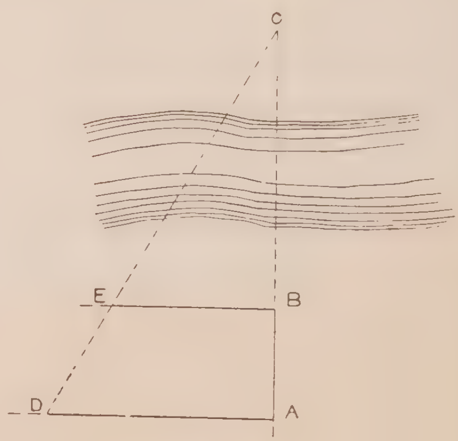


Fig. 2.

Fig. 1 represents an area lined out in the manner aforesaid. It will be noticed that the lines divide it into a series of triangles; these are purposely made as nearly equilateral as possible. The actual work of ranging and chaining cannot well be explained here; suffice it to say that the line must lie absolutely straight between the stations. The arrows are

put down by the "leader" and withdrawn by the "follower"; thus the number of chain lengths may be easily counted. When the follower has acquired the 10 arrows an entry is made in the field-book, and the leader retakes possession of them. As a plan is the horizontal delineation of the ground surface, all measurements taken upon an incline of,

Fig. 3.

say, more than 5° must be reduced to their horizontal value. If the slope is not very steep this can be accomplished by holding the chain, or a portion of it, horizontally and marking the distance with a pole placed vertically, or preferably a plumb-bob; this is known as "stepping." Another method is to calculate the horizontal distance from the angle of the slope. It frequently happens that a chain line is interrupted by some obstacle such as a river or a building. In the former case, if $A\ B$ (Fig. 2) is the line, and the river is too wide to chain across, but the distance $B\ C$ is required, range point C in line with $A\ B$ and set out perpendiculars $A\ D$, $B\ E$, range E with $C\ D$, then:—

$$B\ C = \frac{A\ B \times B\ E}{A\ D - B\ E}.$$

If the obstacle interferes with the line of sight, the chain line may be continued by setting out $A\ C$, $B\ D$ (Fig. 3) perpendicular to $A\ B$ and equal to each other, and ranging $E\ F$ with $C\ D$ and erecting perpendiculars equal to $A\ C$ and $B\ D$ at $E\ G$ and $F\ H$. A perpendicular is best set out with some angular instrument, such as an optical square, but it may be done with 80 links of the chain by placing arrows 40 links apart on the chain line, as a base, and forming the hypotenuse and perpendicular of a triangle with 50 and 30 links respectively (see Fig. 4). Fig. 5 represents a chain survey of a small estate; the pages of the field-book corresponding thereto are shown by figures. In plotting the work on paper the chain lines and stations are first laid down and checked by the tie lines, the detail being afterwards added. This drawing would be kept for reference and a tracing or copy, omitting the survey lines, made from it. The compass point, corrected to the true meridian, is always inserted.

Angle Measuring Instruments. — To adequately describe the many instruments used in surveying would need a treatise; only the more important ones can here be mentioned and their chief uses indicated.

The optical square has already been alluded to; it is an inexpensive pocket instrument by which right angles may be set out. This is sometimes done, but not so reliably, with the cross staff. The angle of a line with the magnetic meridian may be observed with a prismatic compass, another pocket instrument. It is often used for filling in the detail work of a large survey. The box sextant is equally portable, but capable of a nicer adjustment; angles in a vertical, as well as a horizontal, plane can be determined by it. Of all angular measuring instruments, the theodolite is the most important. It consists of a telescope (similar to that of a "dumpy" level, except that the diaphragm markings are different) which may be moved through vertical and horizontal planes. Means are provided for closely measuring the angular movement of the optical axis of the telescope;

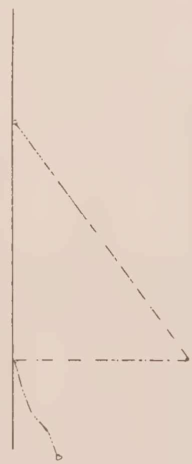


Fig. 4.

spirit-levels and a compass are also fitted. The bearings of two lines from the observer's station to two distant points, one with the other, either in a vertical or horizontal plane, may therefore be taken with great exactitude. The relation of a horizontal line with the magnetic meridian can also be ascertained.

Surveying with the Theodolite.—Many surveys would be extremely tedious and difficult, and even impossible, without the theodolite or its equivalent. The long lines of extensive surveys, especially when over undulating ground, are best set out with it. As the angular bearing of these lines can be ascertained with great accuracy by the use of the theodolite, the number of check lines may be reduced. With the theodolite the principles of trigonometry can be applied to determine the position and distance of various points and the height of inaccessible objects. In trigonometrical surveying a suitable base line and

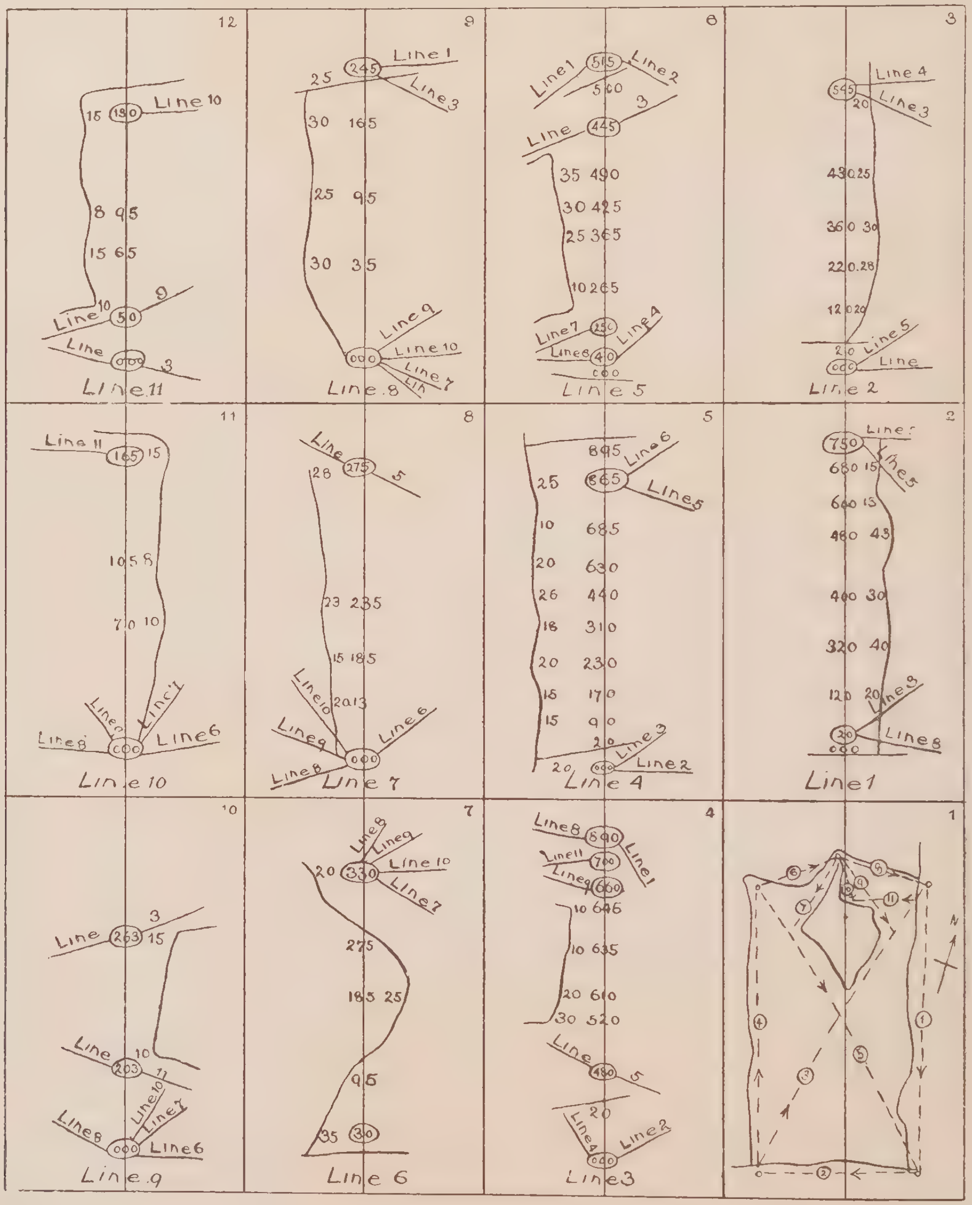


Fig. 5.

the principal stations are carefully chosen and the ground triangulated as in chain surveying. The stations at the extremities of the base line need not necessarily be visible from one another, but it should be possible to observe them easily from the surrounding country. As the system of triangulation is built upon the base line, it is necessary to measure it with the greatest care; in important surveys this is usually done twice. If required, a base line can be extended by angular measurement from suitable points. Although the length of the sides of a triangle may be calculated if the base and the angles included by it and the sides are known, it is necessary to measure at least one of the distant sides of the triangulation as a check. After the main system has been established it is subdivided into smaller triangles and the details worked out as in chain surveying. Lakes, marshes, woods, &c., may be surveyed by inclosing them in a system of lines and observing the angles that these lines make with each other. As the sum of the interior angles should be equal to 90° multiplied by twice the number of sides that the figure formed by the lines contains, less 360°, a proof of their accuracy may be established. If, in plotting the work, the first and last lines do not meet, there is an error in the lineal measurement. This method of surveying is known as a "closed traverse." If done with a chain it would generally be necessary, owing to the difficulty in taking diagonals, to prolong the lines and so form exterior angles, checking the same with tie lines. The courses of winding roads, rivers, &c., are also "traversed"; this again can be more accurately and expeditiously accomplished with the theodolite than by the chain. The line of traverse, along the road or the bank of the river, is usually arranged to start from a definitely fixed point in the general survey and finish on another. In some cases the angles of the various sections of the line are determined in relation to the magnetic meridian. When extreme accuracy is not essential this may be done with the prismatic compass. In town surveying the shape of the streets precludes triangulation, so that the angles of the survey lines must be measured. To obtain a sufficiently long base line is often a matter of considerable difficulty; in some cases a space outside the town is selected for this.

The Ordnance Survey.—The whole of Great Britain has been most elaborately surveyed, and maps to the following scales are published by the Ordnance Survey Department. These may be obtained in London through the appointed agent, Mr. Edward Stanford, of 12 to 14, Long Acre, W.C.

Natural Scale.	Inches to One Mile.	Natural Scale.	Inches to One Mile.
$\frac{1}{500}$	126·720	$\frac{1}{2500}$	25·344
$\frac{1}{528}$	120·0	$\frac{1}{10560}$	6·0
$\frac{1}{1056}$	60·0	$\frac{1}{63360}$	1·0

Besides the above, four smaller scales are also used.

$\frac{1}{500}$th Scale.—Most of the towns of Great Britain have been published to this scale, which generally shows hydrants, lamp-posts, manholes, &c., besides the thickness of walls, spaces between buildings, &c.

$\frac{1}{1056}$th Scale.—The plans of London, Dublin, Belfast, and some small towns are on this scale.

$\frac{1}{2500}$th Scale.—The whole of the cultivated districts of Great Britain (Ireland is in progress) are obtainable on this scale, which shows woods, rough pasture, rocks, &c., in character. The acreage of fields and levels of bench marks are included in the later editions.

$\frac{1}{10560}$th Scale.—Maps to this scale have generally the same detail as the $\frac{1}{2500}$th, but they do not give areas or parcel numbers.

$\frac{1}{63360}$th Scale.—This is the general road map of the country. In addition to the above, maps of the Geological Survey of England and Wales may be obtained. (*See* "Levelling, General Principles of.") E. L. B.

Taps. (*See* "Valves.")

Testing Apparatus.—Drain Plugs.—Made of various patterns, these are all constructed on the same principle. They consist of two metal discs—one fixed to and the other passed over a screwed spindle—between which rests an indiarubber ring. By screwing up a fly-nut on the spindle the two plates are pressed together and the rubber ring expanded and forced out against the periphery of the drain, which is thereby plugged. In the majority of plugs the spindle is hollow and fitted with a cap. This allows of the attachment of the nozzle of a smoke machine, and is useful for the gradual emptying of a drain after testing with water when the pressure is high.

Drain Bags.—India-rubber or waterproofed canvas bladders, which, when inserted in a drain to be plugged, are inflated by means of a small air-pump. They adapt themselves better to any unevenness in the shape of the drain than do drain plugs.

Smoke Machines.—Utilised for the generation of smoke used in drain-testing. They are made of various patterns, but consist generally of a combustion chamber and a pump, fan, or bellows for forcing the smoke into the drains. Smoke is produced by burning oiled cotton waste or "touch paper," which latter is specially prepared brown paper. The machines are provided with a length of tubing for connecting up to the drains.

Smoke Rockets or Smoke Cases.—Cylindrical cardboard cases about 7 in. long and 2 in. in diameter filled with a compound which on ignition generates dense volumes of smoke. Two strips of wood are attached, which, when spread out, keep the rocket off the invert of the drain.

Smell Testers.—Made in many varieties. Consist of small tubes filled with assafœtida or other strong-smelling compound, closed by caps which are held down by paper. When passed into the drains the paper is wetted and thereby softened and broken, allowing the contents of the tubes to be discharged in the drains. Water being thrown into the drainage system, the chemical is passed to all parts of the drains, which it charges with its distinctive smell.

Testing Drains.—The two most reliable tests made use of for proving the soundness of drains are the hydraulic or "water" test and the pneumatic or "air" test. The former is applied by securely plugging the outlet end of the drain (or system of drainage) and filling up the piping with water. When the drain is full, the water level is carefully marked and watched for, say, half an hour. If it remains stationary, the drain is proved sound, in the opposite event a leakage exists. In applying the pneumatic test, all openings on the drainage system or of a section thereof—such as gullies, closets, vent-pipes, &c.—are carefully sealed and air pumped into the drains. The pressure attained is indicated on a gauge (which may simply consist of a U-shaped glass tube charged with water) attached to a plug closing one of the openings in the drain. The gauge being carefully watched after the desired pressure has been obtained, the soundness or leaking conditions of the drains under test will be indicated by the constancy or the diminution in pressure respectively. The pneumatic test in drainage work is superior to the water test in that, in the former, the pressure applied is of uniform severity on each part of the drainage system, whereas it varies greatly in intensity in the case of the water test; the lower portion of the drain having to withstand a much greater pressure under this test than the upper end. The other tests made use of in drainage work are the "smoke" test and the "olfactory" tests. The former is valuable in that the positions of leakages are at once made apparent by the escape of smoke from the drains at the defective points. If the test is applied under pressure it is as valuable as the air test. Without pressure, the results are unreliable, as the absence of escaping smoke does not necessarily imply that the drain is sound, particularly if the pipes are covered by earth. A thin coating of sewage or grease over a defect will also prevent the escape of smoke if

little or no pressure is used. Under the smoke test, smoke generated in a smoke-machine is pumped into the drain through a manhole or other opening in the drains. After the drainage system has been fully charged, all openings are closed and pumping continued until the test has been completed. For convenience of carriage, "smoke-rockets" are frequently made use of in preference to the cumbersome "machine," but as neither the quantity of smoke applied by these, nor its movement in the drains can be controlled, they are of no practical value in the majority of cases.

Olfactory tests consist in charging the drains with some pungent or otherwise distinctive smell, that should be detected at points at which defects exist. Oil of peppermint mixed in a bucketful of hot water and poured into the drains is frequently made use of; while many proprietary testers similarly used are available. These latter are preferable in that the smell is not generated until the interior of the drain or pipe to be tested has been reached. While frequently useful, smell tests are unreliable and cannot be used for proving soundness. G. J. G. J.

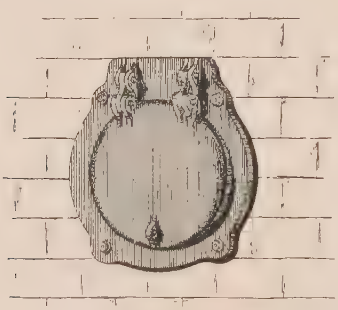
Thermometers.—An ordinary thermometer consists of a fine glass tube with a bulb blown on at one end, and is partly filled with mercury or alcohol. This liquid expands on being heated, and contracts on being cooled. When it expands it passes up along the tube, and by the amount of this expansion the temperature is measured by means of a scale marked off on the tube. In this country Fahrenheit's scale is in general use. In this the freezing point is 32° and the boiling point 212°, the intermediate part of the scale being divided into 180 degrees. In most foreign countries the Centigrade scale is used, in which the freezing point is 0° and the boiling point 100°. All good thermometers have the scale etched on the tube, and it is desirable that they should be verified at the Kew Observatory, so that their errors may be known and allowed for. There are two patterns of maximum thermometer, viz., Negretti & Zambra's and Phillips's. In Negretti & Zambra's maximum thermometer the bore of the tube is reduced in section near the bulb in such a way that whilst the expanding mercury forces itself into the tube, on contraction the column of mercury in the tube breaks off, so that its upper extremity shows the highest temperature that has been attained. In Phillips's maximum thermometer the index is formed by a small portion of the mercurial column, separated from the main thread by a minute air-bubble; this portion is pushed on before the column when the temperature rises, but does not return with it when it falls. The detached portion of the column therefore rests at the extreme position to which it has advanced, and the end of it furthest from the bulb registers the highest temperature which has been attained. Both instruments are set by holding them bulb downwards.

In the minimum thermometer spirit is employed instead of mercury, and in it there is immersed a pin or index. When the temperature falls the surface of the spirit draws the index along with it, but on rising again the spirit passes the index, leaving it at the lowest point to which it has been drawn, the end furthest from the bulb thus registering the minimum temperature. The instrument is set by raising the bulb and allowing the index to slide to the end of the column of spirit. The instruments used for measuring the amount of moisture present in the air are the dry-bulb and wet-bulb thermometers. The dry-bulb is an ordinary thermometer, and shows the temperature of the air; the wet-bulb is a precisely similar thermometer only it has the bulb covered with a piece of muslin, which is kept wet by a conducting thread passing into a vessel of water. If the air is dry it evaporates the moisture from the damp muslin, and in doing so lowers the temperature, and consequently this thermometer reads lower than the dry-bulb.

For meteorological and comparative purposes the dry-bulb, wet-bulb, maximum and minimum thermometers should be mounted

in a Stevenson screen, which is a louvre-boarded box, with their bulbs 4 ft. above the ground. Other thermometers in use at meteorological stations are earth thermometers, for ascertaining the temperature of the soil (the most suitable depths are 1 ft., 2 ft., and 4 ft.); sensitive minimum thermometer on grass, for determining the intensity of terrestrial radiation at night; black-bulb and bright-bulb maximum thermometers *in vacuo*, for determining the intensity of solar radiation. Much interesting and valuable information may be obtained from a self-recording thermometer, such as the Richard thermograph. W. M.

Tidal Valves.—Comparatively heavy metal flaps fixed on the outlet ends of drains discharging into tidal waters, streams liable to



Tidal Valve.

flooding, and in similar positions. The flaps are hinged to the crowns of the pipes in such a way that water or sewage passing through the drains will raise them and issue, while a reverse movement of water (caused by high tides, &c.) will exert a pressure on the valves and close them tightly against the mouths of the pipes; thereby preventing the backing-up of water into the drains.

Tides on Sewer Outfalls, The effect of.—The majority of towns situated on the sea-coast are sewered with one or more outfalls into the sea. In selecting the positions for these outfalls, due attention must be given to tidal currents, and experiments and observations are necessary to determine the direction of flow, the effect of prevailing and other winds, the rise and fall of the tide, and the conditions of the sea bed, whether suitable or otherwise for outfall purposes. The engineer should be acquainted with the peculiarities of the subject of coast work and conditions appurtenant thereto. The question of tidal rivers must also enter into the category, having regard to their tendency to silt up the adjacent sea bed. Tidal rivers, however, frequently afford an advantage in discharging sewage, as the tide ebbs for a longer period than it flows. Great care should be taken to avoid an eddy current, which is common in some situations. Those tides or currents which have a circular movement will frequently prevent the effectual removal of the sewage, and cause it to be deposited on the shore. Sea outfalls should not be constructed to discharge against sea currents unless unavoidable. The chief disadvantage in so doing is that the discharge is impeded, whilst by adopting directions which are parallel with the currents, the flow in the outfall will frequently be considerably accelerated. Attention should be paid to the relative position of outfalls, with regard to the situation of towns, care being taken that the sewage, after being discharged into the sea, does not flow in front of the thickly inhabited parts of the district. It should rather be carried directly away from all town beaches and seaside attractions. Inattention to this important consideration may result in destroying the chief attractions of many places, by rendering their bathing beaches insanitary. One of the most important questions requiring attention is that of the rise and fall of the tide. This must be accurately ascertained, and taken into consideration, in conjunction with the survey of the district to be drained. It will then be seen whether or not an outfall site can be secured, by which the sewage will all flow and discharge by gravitation, or whether pumping or other means will have to be resorted to. Although spring tides rise to a higher level than neap tides, the engineer often has greater difficulty in effecting a good outfall on the neap tides.

Spring tides present not only the highest, but also the lowest tide levels, but the reverse obtains in the case of neap tides, as these neither ebb so low nor flow so high, and therefore the sewer outfall is partially obstructed during this latter period. The discharge chart must be calculated on the difference of head of water within the sewer and over it during neap tides, having due regard to the influences of prevailing winds, which will in some situations have considerable effect in checking the flow of the tide. In a large number of cases where a gravitating outfall cannot be provided on account of insufficient levels, a system of storage can be adopted to meet the requirements of the district, avoiding the initial and working costs of a pumping plant. If it can be so arranged, the outfall should be placed in such a position as will allow a combined system of storage and gravitation as designed and carried out by the writer for the West Penwith District Council. In this case the outfall was carried diagonally under the foreshore, to a discharging point beyond the boundary, and in the favourable direction of the currents and prevailing winds. The sewers from both the high and low levels were by this means caused to converge towards a central point, and whilst the sewage from the lower district was impounded at certain periods of the tides, that from the higher levels discharged through the one outfall pipe, common to both districts, continuously. It was found necessary to store one-third of the combined sewage and rainfall from the low level district on each tide. A tank sewer was constructed for this purpose, having a penstock and valve chamber with midfeather, at the outfall end. The main sewer for the high levels was terminated in the outer chamber, and, on account of its greater head, discharged through the outfall pipe at all states of the tide, whilst the low level remained locked back by self-acting balance valves, fitted on the midfeather and chamber, for the purpose of shutting out the tides until such times as the valves were freed and the sewage released by the inside pressure overcoming that on the outside. In constructing outfalls, particular attention should be directed to the foundation upon which the pipes are to be carried to prevent the undermining action of the waves and currents. F. L.

Town Planning. — **General Principles—Existing Powers—Example of Germany—Zone System—Town Planning Act—Sweden—Holland—Houses per Acre—Town Planning in England.** —Parliament, and most municipal experts now recognise how important it is to establish and regulate a proper system of town development, which shall provide for the organised dispersion of the population of overcrowded centres to residential suburbs, industrial villages detached from the main centre, and to an agricultural belt on the outskirts. The developments that are taking place in the transmission of electric power point to large movements in this direction, because they will make it possible not only for industries to be carried on at distances from the centre, but also for such a cheapening and improvement of the means of transit for both goods and passengers as will tend to minimise the obstacles of time and distance, which at present (though to a less extent than formerly) render it necessary to crowd factories and population in central districts. Cheap transit alone, however, has inflicted on us jerry-built suburban houses of the wrong type, overcrowded on area, and has inflated the price of land for the benefit of the speculators, who too often absorb the difference between the old rent paid on the dear land in the centre and the true economic ground-rent that should be paid for the agricultural land on the outskirts. Hence it is vitally important that the control and ownership of suburban land should be more in the hands of the community than at present, and that one and the same authority should have powers over transit, land, and housing, so as to prevent the creation of new slum areas and excessive increases in the cost of acquiring land for housing and other public purposes as well as to provide for open spaces, main roads, and streets of

adequate width in the proper direction, and in sufficient numbers to meet future needs, before the land near them is forced up to speculative building prices. Town planning is the art of planning towns in respect of the distribution of buildings and open spaces and the provision of streets and roads suitable to each area. It implies a public authority, possessed of power to control, guide and regulate the growth and development of towns, especially as regards building sites, their approaches and surroundings.

Existing Powers. — At present, in the United Kingdom, the majority of these matters are settled by the owners of the land, subject to local by-laws applying practically the same methods and principles to all parts of the town. It is true plans of "new streets" must be submitted to the local authority for approval, but, except in rare instances, no such authority can insist on a plan of the whole of a building estate showing the relations of the intended "new streets" to others adjoining. In most towns there has been no power to vary the direction or position of the streets shown on the owner's deposited plan, but Leeds, Nottingham, Barrow-in-Furness, Blackburn, Bournemouth, Bradford, and Brighton have certain powers in this respect subject to a compensation clause. The Public Health Act, 1907, sections 17 and 22, makes these powers general wherever the Act is adopted. In a great many towns the corporation has obtained power by means of a local Act to prescribe a building line subject to a compensation clause. There are also limited powers, varying considerably as between one town and another, for regulating the area of air space at the side or rear of dwellings, from a minimum of 100 sq. ft. in Bacup to a minimum of 500 sq. ft. in Croydon, but the most generally prescribed area is about 150 sq. ft. As to width, streets are divided into classes in respect of which the requirements of towns vary considerably. The normal width prescribed is 36 ft., but by means of local Acts, streets are classified in some towns such as Cardiff, Nottingham, Leicester, Bolton, Huddersfield, and Sunderland, in various widths, according to their situation and probable uses. Barrow-in-Furness' local Act prescribes varying widths of 80, 60, 40, and 20 ft., and gives power to the corporation at their discretion to reduce the width of the street if an open space is left along one or both sides of the street, in front of the houses. Even when used to their fullest extent, however, these powers are inadequate to prevent the growth of ugly suburbs and mean streets, or to secure for the inhabitants a sufficient supply of the essentials of a healthy life viz., sunlight, fresh air, and vegetation. There are at present no statutory powers capable of effectively dealing with the question of town planning in the United Kingdom, yet consideration of this subject dates back at least 4,000 years, and there are numerous examples of what was done in this connection by the Romans and Assyrians, and even in this country, the town of Winchelsea was planned by Edward I. in the Middle Ages. In Continental towns, notably in Germany, matters are more advanced, and although many parts of these towns are planned on wrong lines, especially as regards the width and nature of streets, yet many of the evils from which our towns suffer have been avoided, while the division of building land near towns into plots, and the choice of the style of building is regarded as the concern of the community, and one coherent official plan is supplied by the town councils to the whole of the unbuilt-on land within the town boundaries, deciding beforehand the general character of building to be allowed in the various parts of the area, according to their anticipated needs. Mr. T. C. Horsfall has done much to familiarise us with German experience in this connection.

The Example of Germany.—In Germany, town plans are generally prepared for so large an area that "the needs of the near future" are provided for, and this phrase is generally taken to mean about 25 years. Dr. Stubben, a great German authority on the subject, says that the first thing to be settled in a town

plan is the position, direction, and width of the principal streets, and this should be followed by a general indication of the mode of division of the land into sites, which must be so arranged with regard to each other that the demands of traffic, health, and beauty may be complied with as fully as possible. While streets and open squares serve for traffic it is important so to construct them that they may be of pleasant appearance, and this can be gained by securing a variety of street forms and well inclosed squares, avoiding in all cases too long straight lines. Principal traffic streets ought to be from 60 to 120 ft. wide, secondary traffic streets 40 to 60 ft., sometimes with front gardens, and streets used mainly for access to the dwellings in them, 25 to 40 ft., often with front gardens. It is this narrowing of the macadamised area, and increase of the open garden space that is so much needed in German town planning to-day. Dr. Mewes, of Dusseldorf, in laying down the elements of a town plan, urges that there should be a general plan, providing for main roads and transit facilities, careful grading of districts in zones providing for different types of buildings in each, but with one or two districts for mixed buildings; varied streets and open spaces; reservation of front gardens for future widening of streets if necessary, and, as in Baden, Hamburg, and Frankfurt, plots belonging to different owners should, where necessary, be pooled and re-apportioned. The law under which this last-named operation is effected in Frankfurt is known as the "Lex Ordickes." Within the area covered by the town plan, there should be varied building by-laws providing for restrictions on the extensive use of land according to its position, and also on the height of buildings, besides providing for cheaper types of streets in purely residential quarters, and relaxed conditions as to the construction of buildings.

Zone System.—An important feature of town planning is the principle of dividing land which is going to be built on into different districts, each, or each group, of which has its own building by-laws. Under this system (known as the "Zone System") some districts are reserved for factories and works, other districts are reserved for dwellings, to the exclusion of factories and works, while yet other districts permit of a mixture of the two classes of buildings. In districts given up to buildings near the centre of the town, five-storey houses built in rows, and covering a large proportion of the site, are allowed; in other districts, the limit is four storeys, and the unbuilt-on area of the site is larger; in other districts, no houses may have more than three storeys, while towards the outskirts, where land is cheaper, only detached or semi-detached houses of two storeys are permitted, and with a good deal of land round them, so as to interfere as little as possible with the supply of air passing towards the central districts.

In Germany, nearly all town councils of important towns, after having plans prepared by their own skilled officials under the direction of a committee of the town council specially qualified for this work, submit such plans for revision to experts of reputation for their skill in suggesting how to make towns convenient for traffic as well as healthy and beautiful. When the plan has received the alterations that these experts suggest, it is submitted to public examination, and any citizen is at liberty to make any objection he likes to any of the proposals. When these alterations or suggestions have been considered, the plan becomes law, with or without the necessary corrections, and all land-owners, in developing their estates, have to comply with the directions laid down.

Town Planning Act.—The Town Planning Act of 1909 was a considerable step forward in the housing legislation of the United Kingdom. By it future developments will be carried out on quite a different system to that prevailing in the past. Town planning schemes may be prepared by either a local authority or land-owners in respect to "any land likely to be used for building purposes and of any neighbouring land." In any such scheme provision shall

be made for open spaces, roads, streets, parks, pleasure or recreation grounds, or for any work incidental to a town planning scheme, whether in the nature of building work or not. Provision is made for the modification or extension of any original proposals. The approval of the Local Government Board is necessary, and this shall be published in the *London Gazette*. Any objections must be made within twenty-one days of publication, and if this is done, then the draft order confirming the scheme must be laid before both Houses of Parliament for thirty days. Should either House present an address against the draft no further proceedings can be taken. It is important, however, not to confound town planning with site planning. The former deals with towns as a whole, and includes all the points mentioned in the preceding paragraphs relating to Germany, whereas site planning is merely the planning of patches of land in one part of a town, without necessarily considering its relations to the development of the town as a whole. While eminently desirable in itself, this latter process would not meet the case of municipalities, who, in the past, have had to spend enormous sums for widening streets, and may have to do so in the future. In order to ascertain how to apply town planning to England it will be useful to study the principles embodied in the town planning laws of other countries. Some of the most recent town planning provisions are those contained in the General Building Law for the Kingdom of Saxony, of July 1st, 1900, as follows:—"Local authorities must prepare a building plan for all unbuilt-on land, and may prepare a plan for a district already built on." The plan may regulate (1) the building lines upon which the sites may be built on, and by which the areas intended for traffic or for front gardens are to be divided; (2) the mode of building; (3) the distance of buildings from the street lines and, therefore, the boundaries of adjoining sites; (4) the height and depth of buildings; (5) the permissibleness of trade buildings in certain districts; (6) the provision of a suitable supply of water and proper drainage; (7) the prevention of disfigurement of streets or squares; (8) the adaptation of street and building lines to the configuration of the land; (9) the securing of an adequate supply of sunshine in the dwellings; (10) the width and nature of streets and foot-paths according to the requirements of local traffic.

The graduation of the width of streets is as follows:—Private back roads, 20 ft.; macadamised area of streets used only for dwellings, 25 ft.; all streets with continuous buildings, 40 ft.; those with much business or through traffic, 56 ft. wide, at least. The gradients in streets must be distributed as evenly as possible, and long straight lines avoided:—In determining the directions of streets, care must be taken to provide short and convenient connection between streets and the chief centres of traffic. Open spaces and public shrubberies must be arranged in convenient and accessible positions. Sites for churches, school buildings, and public playgrounds must be provided in sufficient number. Continuous lines of buildings must be interrupted in sufficient measure by streets. In the outer districts, a suitable restriction of the density of building and population must be made. Front gardens must, as a rule, have a depth of at least 15 ft., and courts and back gardens must be permanently secured as such by regulations respecting their area and position, or by back building lines. Every person who builds must supply, at his own cost, the land for the streets indicated in the building plan along his building plot to a width of 84 ft. in the case of streets which will have buildings on both sides, and he must open up the land, and make it over to the town; unless the town itself undertakes this, he must make it into part of the street, and sewer it. In the interests of traffic or of health, existing buildings in a whole district may be compulsorily acquired by the town council, with the sanction of the Ministry of the Interior, while power is given to purchase immediately, by compulsion if necessary, any land shown on the building plan as a proposed

open space. Local by-laws may be made, providing whether houses must be detached or semi-detached, or built in continuous rows. Ugly or disfiguring buildings can be prohibited, and by-laws may prescribe higher demands in respect of architectural character and appearance of buildings to be erected in certain streets or parts of streets.

Town Planning in Sweden—The Swedish Town Planning Law of 1874, Section 12, lays down some of the main points to be aimed at in town planning, as follows :—

(*a*) That streets shall be wide and shall run in the directions most suitable for traffic.

(*b*) That large and suitable sites shall be provided for markets, harbours, and other places where there will be much traffic.

(*c*) That wide promenades or boulevards, with shrubberies in the middle, and roadways on either side, or with other suitable arrangements, shall traverse the town if possible in various places and in different directions.

(*d*) That as many as possible other public planted open spaces shall be provided in the town.

(*e*) That on the one hand the residential districts shall not be so large nor so crowded with houses as to prevent the free passage of fresh air, or to interfere with the work of extinguishing fires, and, on the other hand, that in the said districts, the building sites shall be of sufficient size to allow of the erection of commodious dwellings, and the provision of open and well-ventilated yards.

Section 13 prescribes widths of roads as follows :—

Normal width, 58½ ft. Specially exempted short streets, roads at sides of boulevards, and streets with buildings only on one side, may have a width of only 39 ft. "Streets which have front gardens on one side or on both sides of them, provided that the distance between the two rows of houses is at least 59½ ft., may also have a width of not less than 39 ft."

Holland.—Under the Housing Act of 1901, Local Authorities in Holland have large powers of land purchase in connection with town planning schemes. Amsterdam has purchased 4 square miles of land, and its suburbs, of which 2 square miles were taken compulsorily, and half the total (2 square miles), has been planned as follows :—

Streets, canals, and squares, 420 acres, or 35 °/ₒ of the area.

Sites for exhibitions, recreation ground and parks, 300 acres, or 25 °/ₒ.

Sites for dwellings in streets or terraces, 280 acres.

Sites for villas and separately-built dwellings, 200 acres.

No street can be built without the consent of the Municipal Council, which has to approve the width, level, direction, and method of construction.

Local authorities are also empowered to prohibit building or re-building on sites that have been reserved for streets, canals, or squares, in any part of the existing towns.

Houses per Acre.—In considering that part of town planning which is concerned with the proportion of building sites that may be covered by buildings, the following table may be of interest :—

Country.	Proportion of Building Site that may be covered by Buildings.
Austria . .	85 % in majority of cases.
Belgium . .	80 %.
Germany . .	33 to 66 %.
Holland . .	75 % in most cases, varying, however, from 20 % in rural districts to 80 % in urban areas.
Italy . . .	The working-class houses must occupy not more than 80 %. (In Turin the proportion is 66 %.)

In Belgium the height of buildings is determined by the width of streets, so that, generally speaking, the building may have a height equal to the width of the street, plus 20 ft. ; in France, the free space opposite a window must be over 15 ft., and in some parts of Paris 30 ft.

Town Planning in England.—In the application of town planning to England the following requirements are desirable : (1) provision for an agricultural belt, which should

be kept permanently free from any large number of buildings; (2) the planning of the district as a whole, providing for "reserves" of open space and for large main roads for motor traffic and trams, with side roads for shops, factories, dwelling-houses, and public buildings, while roads little used for thoroughfares should be of quite a different type; (3) the development of separate sites by means of a special application or modification of the by-laws limiting the number of rooms per acre according to circumstances. Before preparing a town plan there should be a preliminary survey and inquiry to collect detailed information, historical, recent and present, as to all the factors affecting the growth of the town. Maps and plans should be prepared; drawings, photographs, pictures, statistics, and other detailed information should be secured dealing with means of communication, present and anticipated growth, movement, occupations, and distribution of population, with anticipated requirements; lines of growth and expansion, and local changes affecting streets, open spaces, and amenities. There should also be collected town plans from other cities, and the whole of the material so obtained should be exhibited in order that suggestions could be offered by the public in the Press, and by experts, in addition to the proposals drawn up by the municipal authorities. Suggestions and designs should be invited from all quarters, and utilised or rejected after due consideration. Professor Geddes offers a valuable warning when he urges that the essential problem is to discern "the different character and spirit of each town, small or great, Chelsea or Westminster, Dunfermline or Edinburgh, Galway or Dublin, and to collaborate, plan, and work towards a design which shall increasingly express and develop all that is best in these, and here (as in individual life) we may best correct faults by developing qualities. Town plans which omit this individual point of view, which has nowhere been sufficiently considered, are not even adequate as 'town patches.' Thus, the great American seaport would not copy the modern defects of Berlin if it knew the best, say, of Hamburg and Lubeck, old and new." He also does right in urging us to "avoid a too crude and hasty adoption of city plans, inspired not by local life, by love, or knowledge, but by imitation of the costly and meretricious pomposities of great Continental capitals. Haussmann's Paris, the Ecole des Beaux Arts, Modern Berlin and Vienna, have, in this respect, a widening influence upon their annually increasing multitude of visitors from America and Britain; and already the visitors to almost any important city of these islands, must see this influence. For this increasingly threatens us with dreary perspectives and conventional ornament, relieved only by occasional extravagances, and is thus, as with the least artistic sense and training any one can see for himself, even uglier than the, as yet, prevalent industrial squalor and garishness of our poorer quarters, or even than the featureless monotony of our respectable ones. In a word, an immediate danger in America (and in Britain also) is to repeat the mistakes of the French 'city improvers' of the Second Empire, and the corresponding developments of Berlin, Strasburg, &c." W. T.

Trade Effluents.—The rapid development of industries producing effluents containing waste products either in suspension or solution has greatly increased the pollution of rivers in manufacturing centres. The purification of these effluents either alone or when mixed with ordinary sewage forms a special problem and has been the subject of considerable special legislation. The polluting effect of trade effluents may be due to the presence of: (*a*) an excessive quantity of suspended solids; (*b*) substances capable of fermentation or putrefaction and consequent production of nuisance; (*c*) colouring matters such as vegetable or artificial dye-stuffs; (*d*) substances poisonous to aquatic vegetation or fish life; (*e*) oily matters, fat and soap.

The detailed description of these various classes of effluents and their respective

methods of treatment is briefly indicated in the following paragraphs, it being understood that one effluent may fall under more than one head.

(*a*) Tannery effluents contain large quantities of lime in suspension; effluents from plants for the recovery of ammonia from liquors produced in the distillation of coal in gas-retorts or coke ovens contain large quantities of lime and calcium sulphide and sulphate in suspension; effluents from coal-washing plants contain much fine coal in suspension; pottery effluents contain clay; effluents from aniline stills may contain large quantities of magnetic oxide of iron; effluents from dye and bleach works may contain much flocculent matter from waste "filling" or mordanting substances and fibrous material from the cloth itself; paper-mill effluents may also contain fibre and "filling." Most of these can be clarified by simple subsidence in suitably constructed settling tanks. In certain cases, *e.g.*, for paper-mill effluents, mechanical filters or fine screens may be employed. (*b*) Among important fermentative or putrefactive effluents are those from breweries and distilleries, from tanneries and hide-dressing works, from beetroot sugar factories, starch works, wool-scouring works, bone manure and glue factories. All of these can be purified by suitably-arranged biological tanks and filters, either at the actual works producing the effluent, or mixed with sewage at the works of the local authority. It should be noted that liquids capable of undergoing acid fermentation, *e.g.*, starchy effluents or brewery effluents are not well suited for anaërobic treatment. (*c*) Colouring matters from dye-works may be of vegetable origin, such as indigo or logwood, or belong to the numberless varieties of so-called "aniline" or artificial dye-stuffs. The former and certain of the latter, *e.g.*, alizarine derivatives, which are fixed by mordants, can be precipitated by means of iron or aluminium salts. A large proportion of artificial colouring matters are not capable of removal in this way. They are generally destroyed in biological filters when mixed with sewage, but apart from their colour do not constitute a dangerous element in effluents. (*d*) A great variety of injurious substances may be discharged under this head, *e.g.*, alkaline sulphides from alkali waste heaps, from the vulcanising of india-rubber, from dyeing processes employing sulphur dye stuffs, and in certain cases the effluents from ammonia recovery stills. It is highly important that these should be treated either with excess of lime or a mixture of lime and ferrous sulphate (copperas), and the precipitated sulphide settled out in tanks, before the effluent is discharged either into a sewer or a water-course, or there is almost a certainty of serious nuisance or even fatal accidents arising from the evolution of sulphuretted hydrogen, due to chance contact of such an effluent with free acid.

Acids and alkalis unless present in very minute proportion should be neutralised before discharge into a stream or sewer.

Chlorine either in the free state or as hypochlorite in bleach works effluents, unless present in very large quantities, is not likely to be very troublesome when discharged into a sewer, but it is important, from the point of view of fish life and aquatic vegetation, that only nominal quantities should be allowed to pass direct into a stream. Numerous tarry products such as benzol and naphthalene washings containing sulphuric acids of benzene and naphthalene, various phenolic derivatives, &c., are very injurious to the microscopic life of streams, and may in some cases quite upset the natural balance of aquatic life. When sufficiently diluted and mixed with sewage, they are amenable in general to biological treatment. The same applies to the very troublesome effluents from ammonia stills treating the liquor from the distillation of coal in retorts or coke ovens. In addition to phenolic derivatives these effluents contain sulphocyanates, thiosulphates, and sometimes sulphides. The effluents from paper and cellulose works obtained after boiling raw cellulose material with alkaline sulphites is very difficult to treat and is generally

evaporated. (*e*) Free particles of grease and fat, *e.g.*, from tripe-dressing works, &c., can usually be intercepted by specially devised grease traps, of which there are several, *e.g.*, the Kremer apparatus and the Eric Mesten apparatus.

Soaps, *e.g.*, such as are produced in wool-scouring works, are first broken up by acid, when the fatty acids rise to the surface and can be separated and purified. In the case of ordinary laundries it is often simpler to precipitate the soaps with lime.

Law as to Trade Effluents.—The general law as to trade effluents is to be found in the Public Health Act, 1875, the Rivers Pollution Act, 1876, The Public Health Acts Amendment Act, 1890. The difficulties of interpretation of the law have centred round the liability of local authorities to take trade effluents into sewers, when either these were insufficient in size or when, the sewers being adequate, the purifying works were overburdened. A further difficulty has arisen in regard to responsibility for pollution of a stream, when a manufacturer discharges into a sewer belonging to a local authority. Typical cases illustrating each of these three difficulties are, respectively: *Peebles* v. *Oswaldtwistle Local Board*, 1898; *Brook, Ltd.* v. *Meltham Urban District Council*, September, 1908; *Butterworth & Roberts* v. *West Riding Rivers Board*, November 26, 1908. All of these have been decided on appeal in a sense favourable to the local authority. It is generally the wish of the local authority to encourage manufacturers as far as possible, and several towns have special by-laws of their own obtained generally by mutual agreement with manufacturers, confirmed in some cases by special Acts of Parliament. Thus, the towns of Bradford and Halifax have power to impose a charge upon manufacturers, according to the volume and quality of the effluents sent into the sewers; Manchester has special powers regulating the composition of the effluents discharged into the sewers, but does not make any charge for treatment. These powers are based on similar ones possessed by the London County Council. The Royal Commission on Sewage Disposal recommended in their third report, 1903, that in general local authorities should receive trade effluents into sewers, but that either preliminary treatment should be adopted by the manufacturer or he should pay a special charge to go to the cost of treatment of his effluent. Points of difference likely to arise between manufacturers and local authorities, they recommend, should be referred to the central authority which they are of opinion should be appointed.

G. J. F.

Tramways, Municipal.—**Overhead Trolley System — Conduit System — Surface Contact System—Comparison of Tramway Systems.**—A tramway system comprising not more than twenty or thirty cars should purchase its electricity from some large electricity supply station, wherever such is available. The multiplication of small stations is a mistaken policy, and is largely responsible for the unsatisfactory commercial results which have been obtained in the case of a large percentage of the tramways in this country.

For tramway undertakings of any considerable extent, the electricity should first be delivered from the supply station in the high pressure three-phase form. In this form it should be transmitted through three-core paper-insulated lead-covered cables to substations located at appropriate points on the tramway route. The sub-stations should be equipped with motor-generators, by means of which the high pressure three-phase electricity is transformed into continuous electricity at the low pressure of 550 or 600 volts.

This low-pressure electricity is transmitted from the sub-stations to the tramcars by one or other of the following three systems:

1. The Overhead Trolley System.
2. The Conduit System.
3. The Surface Contact System.

1. Overhead Trolley System.—A copper conductor, usually between 2/0 and 4/0 s.w.g. is supported on insulators at a height of

some 20 ft. above the track, by means of transverse steel span wires carried by poles. This overhead copper trolley wire conducts the electricity from the sub-station to the tramcar. The tramcar is supplied with a trolley pole carrying a wheel or bow at its upper end. The wheel or bow travels on the lower surface of the overhead wire, collecting the electricity, which is then conducted to the motors and controlling apparatus on the car. After passing through this apparatus, the electricity is conducted to the car wheels, and thence to the rails. The rails are connected to one another by copper bonds, and thus constitute a conductor by means of which the electricity is conveyed back to the sub-station. Sometimes the rails are welded together instead of being bonded.

2. Conduit System.—The most modern example of tramway construction on the conduit system is that laid down by the London County Council in many parts of London and its suburbs. The conductors are located in a conduit situated midway between the track rails, and the current is collected from these conductors by means of a "plough" passing through a slot in the road bed, and suspended from the car. In one of the earlier forms of conduit construction, the conduit was made a component part of one of the track rails. The track rails were formed by two bull-headed rails, placed side by side, with sufficient space between to allow the collector or "plough" to pass through. The advantage of this side-slot construction is that it does not require keeping gauged, but a strong disadvantage is the impracticability of obtaining a substantial permanent-way for the heavy cars. The London County Council system has the slot midway between the track rails, the slot being formed by Z section rails, bolted at intervals to heavy cast-iron yokes, the width of the slot being maintained as near $\frac{3}{4}$ in. as possible. The slot rail is of steel weighing 60 lbs. per yard, and is 7 in. in height.

Two forms of yokes are used in the system, one, of light weight, to which the slot rails only are bolted, and another, the full width of the track, to which both the slot rails and the track rails are bolted. These two types of yoke are, in special places, such as at curves, &c., placed alternately, but in straight track the full-width yokes are placed about every three yokes, the distance between each yoke being 5 ft. The slot rails have to be stiffened by means of ties fastened to the track rails in order to prevent the slot from closing under the influence of the crushing effect of other traffic upon the paving between the slot and track rails. The conductors are two in number and are of soft steel tees weighing 22 lbs. to the yard. They have a contact surface $3\frac{1}{2}$ in. in depth, and are supported on special insulators, spaced 15 ft. apart, and situated between the yokes.

The depth from the top of the slot rail to the bottom of the conduit tube is 1 ft. $9\frac{1}{2}$ in., and to the base of the yokes, where the latter bear in the concrete bed, 1 ft. 11in. Thus, during the construction of a conduit system, all gas, water and other pipes, cables, sewers, &c., must be sunk at least 23 in. below the surface of the road, before the conduit can be laid down.

The "plough" or collecting device consists of two soft cast-iron shoes, supported by pieces of maple wood, which are stiffened and supported by means of mild steel plates, passing through the slot, these steel plates being flexibly hung from the under-frame of the car. The shoes are pressed against the face of the tee conductors by means of substantial springs.

To allow proper draining and sanitation of the conduits, they are, at intervals along the route, connected to the main sewers, which generally run along the side of the conduit.

3. Surface Contact System.—There have been many surface contact systems invented, but few have actually been put into practice. These latter have, moreover, usually proved utterly unreliable. The surface contact system consists essentially of contact studs, located at intervals of about 15 ft. apart, situated midway between the track rails, and

from which the current is collected by means of "skates." The two essential conditions which must be fulfilled in a system of this kind are:—

(1) The contact stud must not be alive when the car is not over it, *i.e.*, when the car is not drawing energy from it, and

(2) Some arrangement has to be provided to make the contact stud alive when the car approaches it. Apparently one of the least unsuccessful of all the systems on these principles is that commonly known as the "G. B. System." In this system the current from the generating station is conveyed through a bare stranded galvanised iron cable, carried on insulators in a 5 in. stoneware pipe which serves as a conduit. Connection between the conductor and the contact stud is effected magnetically by means of powerful magnets carried on the car. When these car magnets come over the contact stud, a plunger switch, having a carbon contact, immediately makes contact with the iron cable conductor. When the car leaves the stud, the plunger switch is immediately disconnected by means of a powerful spring. The excavation necessary with this system does not exceed 19 in., and this can be considerably reduced in special places where so great a depth is inexpedient.

Comparison of Tramway Systems.— The most important applications of the overhead trolley systems are in country districts and in towns of fairly small population. In some large towns, overhead trolley systems are often prohibited. In residential districts, objections based on æsthetic grounds are often brought up against the system. Nevertheless very nearly all of the tramway undertakings in the United Kingdom are constructed on this system. The capital cost of the conduit system precludes its use in purely residential districts. Conduit systems are only appropriate in large towns where a dense service can be maintained, and where, for other reasons, the trolley system is undesirable.

Under normal conditions the cost of trackwork per mile (excluding cables and other items common to all three systems), is somewhat as follows, for the three different systems:—

Conduit System	£17,000.
"G.B. Surface Contact System"	£11,000.
Overhead Trolley System ...	£10,000.

From these figures we see that the conduit system involves a capital outlay approximately £7,000 greater per mile, than in the case of the overhead trolley system. In order to understand the significance of this difference let a simple example be taken. Suppose a tramway system is one mile in length, and a service of two-and-a-half minutes for 16 hours per day is maintained. Then, if we consider a double track the whole length of the system, the car miles per year will amount to

$$2\left(\frac{16 \times 60 \times 365}{2{\cdot}5}\right) = 280000.$$

Allowing 10 % for interest and depreciation, then this £7,000 difference in capital cost between the two systems is equivalent to £700 expenditure per annum.

Thus the difference in interest and depreciation per car mile amounts to some

$$\frac{700 \times 240}{280000} = 0{\cdot}60d.$$

The conduit has to be kept clean, both for insulation and sanitary purposes, and this maintenance cost is certainly at least 0·3*d.* per car mile in excess of the trolley system. Thus the total difference between the two systems amounts to $0{\cdot}60 + 0{\cdot}30 = 0{\cdot}90d.$ per car mile. Assuming an average operating cost of 6·5*d.* for the overhead trolley system, this maintenance and capital cost will represent an extra 13 %, or a total operating cost of 7·4*d.* per car mile for the conduit system.

In the conduit system there are no electrolytic actions occurring in water pipes and elsewhere, due to currents leaking from the return conductor, because an insulated conductor in the conduit itself serves to carry the return current, whilst in the trolley system the current is returned through the track rails. It is with a view to minimising electrolytic damage to underground pipes and structures

that the Board of Trade require that, with the overhead trolley system, the drop of pressure in the rail return shall never exceed 7 volts.

From the point of view of the safety of the public, the conduit system undoubtedly possesses some advantage. There are no "live" wires above the ground, and it is impossible to touch the conductor in the conduit by any ordinary means, through the slot opening. With overhead construction, the Board of Trade require protection for telephone wires and cables which may happen to cross the trolley wire. That is to say, if a telephone wire breaks, it must not be possible for it to fall across the "live" wires. To prevent this, grounded "guard" wires are suspended above the trolley wires.

As regards durability, the steel conductors of the conduit system have a longer life than the ordinary copper trolley wire. The latter in ordinary services will last some 4 years.

A disadvantage of the conduit system lies in the fact that the slot is very liable to close, due to the pressure of the wood or stone paving. Thus the plough is liable to become wedged in the slot and cause delay in the traffic.

The serious difficulty with the surface contact system is its unreliability. Experience has proved that the studs are sometimes left alive, in spite of every precaution to render such occurrences impossible. In view of this difficulty, extra skates are sometimes provided on each car. These trail behind the collecting skate, and in case of a stud being left alive the trailing skate directly short-circuits the stud with the track rail, thus putting the stud out of action for the time being. The maintenance costs of the surface contact system are certainly not less and are usually far higher than for either the trolley or conduit systems, and this will occasion no surprise when it is remembered that hundreds of switches per mile have to be kept in thorough working order.

Acts of Parliament affecting the Operation of Municipal Tramways.—Provisional Orders authorising the construction of tramways were granted under the powers of the Tramways Act of 1870. It was stated, however, when the Bill was introduced, that power would be given local authorities only to construct tramways, but not to work them.

The "Purchase Clause" of the Act of 1870 imposed upon the private tramway companies the liability of compulsory sale to the local authority of the district. Under this clause the local authority may, within 6 months after the expiration of 21 years from the granting of the tramway order, and within 6 months after every subsequent period of 7 years, require the promoters to sell their undertaking. It is now possible under the present rules, for municipalities to operate tramways, as well as to construct them. No Act of Parliament, however, authorises them to do so without special grants, and it was due, among other reasons to the difficulty of coming to an understanding as regards lease, &c., with the companies, that led certain municipalities to obtain these special grants.

A municipality is allowed to construct tramways outside its own area, providing the consent of the local authority of the new area is obtained. The local authority of the new area still, however, retains its power of compulsory purchase under the conditions given in the Purchase Clause of the 1870 Act, given above.

The local authorities must obtain the consent of the Board of Trade with respect to the power of borrowing capital.

With regard to constructional obligations, the 1870 Act contains clauses to the effect that no tramway may be so laid that for a distance of 30 ft., less space than 9 ft. 6 in. intervenes between the foot-path and the rail, if one-third of the occupiers abutting on that part of the road dissent.

The tramway constructors are bound to keep the roadway in repair to the extent of 18 in. on each side of their rails, and between double lines.

The Light Railways Act of 1896, although

SUMMARISED RECORDS OF ELECTRIC TRAMWAY UNDERTAKINGS.

	Companies.			Local Authorities.			Total (Companies plus Local Authorities).		
Financial Year	1907	1906	1905	1907–8	1906–7	1905–6	Comp. (1907) Local Auth. (1907–8)	Comp. (1906) Local Auth. (1906–7)	Comp. (1905) Local Auth. (1905–6)
Number of Undertakings	19	23	22	75	72	70	94	95	92
Capital Expenditure at End of Year	£6,532,600	£7,080,000	£6,760,000	£34,896,400	£31,520,000	£28,100,000	£41,429,000	£38,600,000	£34,860,000
Traffic Revenue	£988,000	£968,000	£840,000	£8,009,300	£7,070,000	£6,240,000	£8,997,300	£8,038,000	£7,080,000
Revenue from other Sources	£25,300	£52,400	£22,900	£138,120	£129,000	£108,000	£163,420	£181,400	£130,900
Total Revenue from all Sources	£1,013,500	£1,020,000	£863,000	£8,147,500	£7,190,000	£6,350,000	£9,161,000	£8,210,000	£7,213,000
Operating Costs	£608,000	£602,000	£529,000	£4,936,700	£4,300,000	£3,890,000	£5,544,700	£4,902,000	£4,419,000
Gross Profit	£405,400	£419,000	£334,000	£3,210,700	£2,890,000	£2,460,000	£3,616,100	£3,309,000	£2,794,000
Depreciation and Reserve	£57,900	£57,800	£41,700	£857,400	£726,000	£663,000	£915,300	£783,800	£704,700
Net Profit available for Interest and Dividends	£347,500	£361,000	£292,000	£2,353,300	£2,170,000	£1,800,000	£2,700,800	£25,310,000	£2,092,000
Amount of Gross Profit per £100 of Capital	£6·20	£5·92	£4·94	£9·20	£9·18	£8·76	£7·7	£7·55	£6·85
Amount Provided for Depreciation and Reserve per £100 of Capital	£0·89	£0·82	£0·62	£2·46	£2·30	£2·36	£1·68	£1·56	£1·49
Amount of Net Profit per £100 of Capital	£5·32	£5·10	£4·32	£6·74	£6·87	£6·40	£6·0	£5·98	£5·36
Length of Track in Miles	431·98	431	405	2,231·29	2121·64	1929·56	2663·27	2552·64	2334·56
Number of Car Miles Run	24,343,043	24,789,000	22,113,000	182,639,898	160,755,000	143,346,000	206,982,941	185,544,000	165,459,000
Number of Passengers Carried	190,820,817	192,275,000	163,903,000	1,822,344,841	1,595,893,000	1,412,124,000	2,013,165,658	1,788,168,000	1,576,027,000
Number of Passengers per Car Mile	7·84	7·76	7·41	9·98	9·93	9·85	8·91	8·85	8·63
Traffic Revenue per Car Mile	9·74*d.*	9·37*d.*	9·11*d.*	10·52*d.*	10·55*d.*	10·45*d.*	10·13*d.*	9·96*d.*	9·78*d.*
Average Fare per Passenger	1·24*d.*	1·21*d.*	1·23*d.*	1·05*d.*	1·06*d.*	1·06*d.*	1·14*d.*	1·13*d.*	1·14*d.*
Operating Costs per Passenger	0·76*d.*	0·75*d.*	0·77*d.*	0·65*d.*	0·65*d.*	0·66*d.*	0·70*d.*	0·7*d.*	0·715*d.*
Operating Costs per Car Mile	6·00*d.*	5·82*d.*	5·74*d.*	6·48*d.*	6·42*d.*	6·52*d.*	6·24*d.*	6·12*d.*	6·13*d.*

not applying strictly to tramways, has, however, been applied to a large extent for tramway purposes. The procedure under this Act is governed by rules issued by the Board of Trade.

A very lucid survey of the financial aspects of the municipal tramway situation has been published by Mr. E. Garcke, in a little book entitled "The Progress of Electrical Enterprise," Electrical Press, Ltd., London, 1907. Details of tramway construction are ably set forth in Vol. 1, of Wilson & Lydall's "Electrical Traction." Excellent descriptions of various systems, accompanied by analyses of their finances will be found in Prof. R. H. Smith's "Electric Traction," Harper & Bros., 1905. Another capital treatise on tramways is Ashe & Kelly's "Electric Railways," published in two volumes, by Messrs. Constable & Co., Ltd., London, 1907.

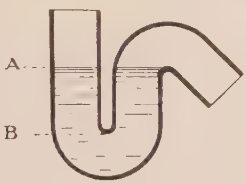
As regards applications of electric traction on a larger scale than for tramways, and to overhead, underground, urban and suburban railways, Parshall & Hobart's "Electric Railway Engineering" may be consulted.

By permission of the publishers of the "Electrical Times," a table, giving the summarised records of electric tramway undertakings has been added. In the first two columns the figures are for private companies for the financial years of 1905 and 1906. In the second two columns are given equivalent figures for tramway

undertakings owned and worked by local authorities for the financial years 1906-7 and 1905-6. In the last two columns, these separate figures for companies and local authorities are added under their equivalent financial years.

For notes with regard to the generation, transmission and transformation of the electricity required for the propulsion of tramcars, see article on "ELECTRICITY."

Trap.—A term applied to the dip or bend in a drain or pipe, which, by retaining water, serves to break the direct line of connection between the air contained by two portions thereof. The water retained is said to "seal" the trap; the effective seal being the portion contained between the standing level of the



Trap.

water and the lowest point of the soffit at the dip of the trap (*A—B* in the illustration). It is the depth of this portion which is referred to by the phrase "a water-seal of so many inches." One-and-a-half inches is considered the minimum seal admissible, and 2½ in. the seal generally accepted as the standard. Traps may be subdivided into traps of fittings, gullies, disconnecting traps and grease traps, as to which see under respective headings.

Traps for Fittings are necessary to exclude from the house foul air generated in waste pipes and surface traps, &c. In the case of water-closets and of most slop hoppers the trap is made as a part of the fitting itself. With lavatory basins, baths, sinks and urinals the trap must be specially provided, and should be fixed on the waste pipe close up to the fitting. Such traps must be, as far as possible, self-cleansing, and should provide an efficient seal with a minimum quantity of water. The only traps at present available which comply with these requirements are the siphon traps drawn from lead piping and made in various forms, such as the "S," "P," and others. All other traps—such as the "Bell" trap, "D" trap, "Bottle" trap, and the "Mechanical" traps in which latter are floating balls or valves—are either inefficient or uncleanly. The traps used must be of the same or of a smaller sectional area than those of the outlets under which they are fixed; due allowance being made for the space obstructed by the outlet gratings. If larger, they will not be properly flushed and cleaned by the discharge of the fittings.

Turbines.—In an ordinary water-wheel only a portion of the periphery is acted upon by the water, but in turbines it is, with few exceptions, directed by guide blades to every vane in the revolving part; the wheel of a turbine thus receives the pressure, or in some cases the impulse, of the water throughout its circumference. For this reason it is much smaller and revolves at a far higher speed than a water-wheel of equal power. Both guides and vanes are curved in such a way

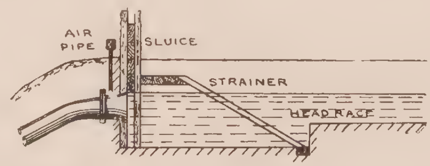


FIG. 1.—Headrace and Supply of Water to Turbine.

that the water passes from one to the other without shock or break of continuity and herein lies the cause of the high efficiency, amounting, under favourable circumstances, to over 80%. Turbines may be of the "pressure" or the "impulse" type. The former are those in which the spaces between the vanes are full and under the pressure of the water. In impulse turbines, such as the "Girard" the water acts by impulse, leaving the guides with a velocity proportionate to the head, and entering the wheel to glide over

the concave surface of the vanes without filling the passages. In some cases the guides of impulse turbines are only applied to a portion of the wheel—this is known as "partial" admission. The "Pelton wheel" belongs to this class—in this case one or more the guide blades, which are then made movable for that purpose, or by throttling the supply with a cylindrical sluice working between the guide chamber and the wheel; in a few cases, however, an adjustable gate is placed at the intake. The first plan gives the

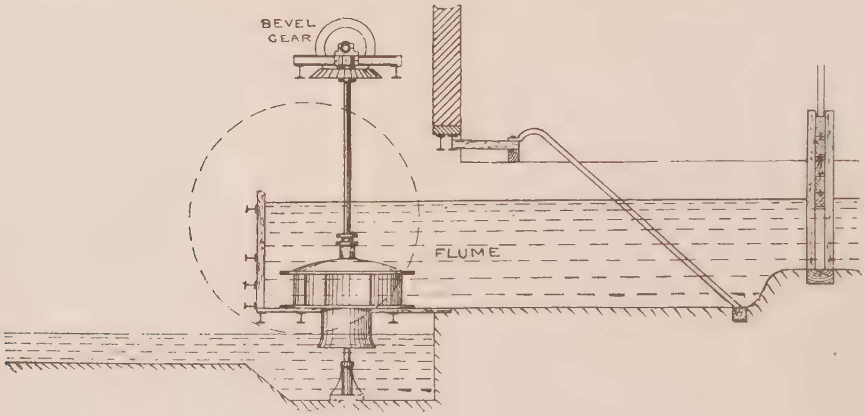


FIG. 2.—General Arrangement of Fixing of Turbine.

tapering nozzles direct a jet of water into double cups placed around the rim of a wheel. Turbines may be classified as "outward," "inward," "parallel" or "mixed" flow, according to the direction in which the water passes through them. In the first type, (Fourneyron's) the guides form the central part of the turbine, the wheel containing the vanes being placed outside it and in the same plane. The water enters the inner portion and is directed by the guide passages to the annulus of vanes surrounding it, giving motion to that part by pressure and reaction and afterwards escaping at its periphery. In the second type ("vortex") the water enters through guide passages on the outside of the wheel and discharges at the centre. With the parallel flow turbine ("Jonval" type) the guides are placed above, or if the shaft is horizontal to one side of the vanes, and the water passes through in a direction parallel with the axis. The mixed type is a combination of the inward and parallel flow, and is represented by the "Francis," "Hercules," "Little Giant," and others. Turbines are usually regulated by varying the opening of most economical regulation under varying loads, but it is more complex and therefore higher in first cost. For low falls where the quantity of water is large, pressure turbines of the parallel and mixed type are the most suitable. Under these circumstances the

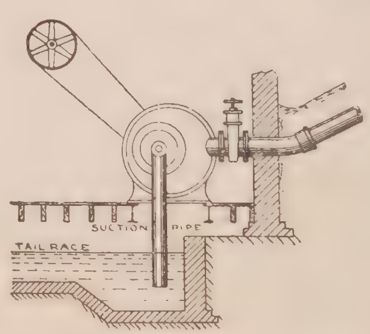


FIG. 3.—"Double Vortex" Turbine.

water is conveyed to the turbine by a "flume" of timber or masonry, the general arrangement being usually as shown in Fig. 2; the dotted circle indicates how a breast wheel might be replaced by a turbine. For moderate falls of 10 ft. and upwards it is generally preferable to inclose the turbine in an iron

case to which the water is conducted by piping. By causing part of the fall to act by suction, a turbine may be placed well above the tail race and the machinery driven by belting or coupled directly to its shaft. Fig. 3 shows a "Double Vortex" installed in this way, but the arrangement would apply generally to any other incased turbine with a horizontal shaft. Fig. 4 illustrates the mode of fixing a Little Giant turbine; in this example the turbine replaced an overshot wheel, the pentrough of which was utilised in the manner shown. A Girard turbine could be similarly arranged except that it would be placed a few inches above tail water to insure a free discharge. Suction tubes cannot be employed in an impulse turbine owing to the passages being only partially filled; therefore, to obtain the full effect of the fall, which in one of low head is important, it must be placed close to the tail water, in which position it is liable to have its efficiency impaired during floods. With high falls a slight sacrifice of head is not of so much consequence, and to them, impulse turbines of the Girard type are specially applicable, as partial admission can be adopted. By this means the diameter of the wheel may be increased and its rotative speed, which in very high falls would tend to become excessive, reduced in proportion. Another feature of the impulse turbine is that its efficiency is practically constant throughout all degrees of admission. When the last consideration is unimportant, the Pelton wheel is very suitable for high falls. (*See* "WATER POWER, WATER WHEELS.") E. L. B.

Typhoid Fever.—This disease appears to affect all communities, and is especially prevalent in urban districts with impure water supplies and imperfect sewerage systems. Fewer cases occur, in proportion to the population, in rural districts, even where the water is notoriously impure and where sanitary conditions generally are unsatisfactory. The explanation doubtless is that amongst the more scattered population the risks of personal infection are far less than in the more densely populated towns. The disease has a marked tendency to increase in prevalency during the autumn, and if for any reason several cases have occurred in the summer quite an outbreak may occur later when the season is more favourable for its spread. The

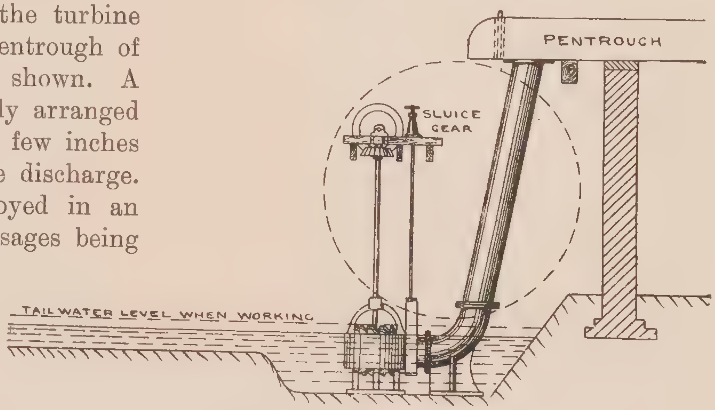


FIG. 4.—Method of fixing "Little Giant" Turbine.

cause of these autumnal outbreaks has not yet been discovered. The infecting agent is a bacillus which can be cultivated outside the human body, but which is somewhat difficult to recognise and exceedingly difficult to isolate when associated with the bacteria found in sewage. In fact, it is not always possible to find it in water which may be known to be causing disease. The bacilli can frequently be discovered in the blood of persons suffering from typhoid fever, but they are far more numerous in the urine and fæces at certain stages of the disease. Recent researches have shown that in some instances, which may be far more numerous than we surmise, the fæces may retain the bacilli many years after recovery from an attack. Such persons are called typhoid "carriers," and several epidemics in public institutions and numerous isolated cases have been traced to these "carriers." From the urine or fæces the bacilli reach the drains and the sewers, and the most recent research has proved that if there is any splashing in such sewers, or any

stagnation leading to putrefaction and the bursting of bubbles of gas, bacilli are discharged into the air, and may be detected at the ventilating openings. No doubt also when infected slops are thrown over badly paved gullies the bacilli may get into the air and infect water, milk, or articles of food. A typhoid carrier of uncleanly habits may spread the disease wherever he goes, but unless some article of food or drink used in common by a large number of persons is infected the cases will not be numerous. When such infection does occur an epidemic may follow. Epidemics are generally due to infection of water, milk, or shell-fish; but some occur which cannot be definitely attributed to these causes. Such outbreaks usually commence in the autumn and follow a series of isolated cases. Usually also it is found that they are associated with grossly insanitary conditions, uncleanliness, overcrowding, defective privies or water-closets, defective drains and sewers, fixed uncovered ash-pits, filthy badly-paved yards, &c. Taking 77 recorded outbreaks which have occurred in this country since 1881, 13 were definitely traced to water, in 17 instances the water was gravely suspected, but absolute proof was wanting, in 4 milk was the cause, in 3 oysters, in 1 cockles, and in 1 watercress. In the remaining 38 cases the cause could not be ascertained, but almost invariably the sanitary circumstances of the districts invaded were bad in the extreme. Water outbreaks would probably be more numerous were it not that the typhoid bacillus rapidly dies out in that medium. Several bacteriologists have demonstrated that 99·9°/₀ of the bacilli die within 7 days. Where a water has been purposely and largely impregnated with the bacilli, an odd bacillus may possibly be discovered for many days afterwards, but whether these more resistant organisms are dangerous or not there is no means of ascertaining. This fact, however, is of great practical importance as showing the great advantage of storage, but whether storage beyond 7 to 10 days is of any great utility from this point of view is very doubtful. Water and milk outbreaks, and outbreaks due to infection of other articles of food or drink, may occur at any period of the year and attack all classes indiscriminately, whilst outbreaks due to unknown causes or to insanitary conditions usually, if not invariably, occur in the autumn and affect the uncleanly and the poor in an excessive proportion. When a town has a common water supply naturally all the persons attacked will have partaken of the water, but unless the disease is fairly uniformly distributed throughout all classes and throughout the town, or throughout an area supplied by a particular main, the water supply cannot be the cause. If the outbreak is localised, or only occurs amongst certain classes, and especially if limited to the more insanitary areas, some other cause than the water must be suspected. Milk may be infected at the farm, or the dairy, or even during distribution; and in the first instance nearly all the patients will be consumers of the implicated milk, though at a later date personal infection will commence. So far as is known, animals do not suffer from typhoid fever, and there is no record of any outbreak having occurred from the contamination of water or milk by animal manure. The bacilli may live for considerable periods in sand and soil, or on dirty surfaces, but most contradictory results have been obtained by different observers. There are reasons for believing, however, that under very favourable circumstances it may survive for many months in surface soil. It is destroyed in a few minutes by a temperature of 70° C. In infected urine and stools it may be killed by a very liberal use of disinfectants, allowed to act for, say, an hour to penetrate the more solid matter.

Although it is doubtful whether it can survive even a few hours in sewage, it is now usual to supply each typhoid patient, not removed to an isolation hospital, with a special pail containing disinfectants for the reception of the urine and fæces. These are changed at regular intervals by the scavenger, and fre-

quently the contents are mixed with sawdust and petroleum and burnt. Experiments made with the common house-fly show that it can convey the bacilli on its feet, and that these may live for some days in the intestine of the insect and be afterwards found in the spots of fæcal deposit. It is probable, therefore, that they can convey infection, and one outbreak attributed to infection of water cisterns by this means has been recorded.

J. C. T.

Typhus Fever.—This fever was for a long period the scourge of Europe, but during the last century it nearly disappeared from England, Wales, and Scotland. Many outbreaks, however, occurred in Ireland during periods of famine. Cases still occur occasionally in our crowded cities, and invariably where the poor are densely aggregated together amidst squalid surroundings. It is one of the most contagious of diseases, more frequently than any other attacking the medical attendant and nurses, or those coming into close contact with the patient. We are unfortunately ignorant of the specific cause, but there is every reason to believe it is a "germ" disease. Its practical disappearance is due to many causes; the improved housing of the poor, diminution of overcrowding, greater general cleanliness, and the higher standard of living. When an outbreak occurs the patients should be promptly removed to an isolation hospital or other place where they can have an abundance of fresh air. Contacts should be carefully watched to detect the earliest symptom of infection. The premises infected should be thoroughly cleaned and disinfected, and every article of bedding or clothing which has been used by the patient should be sterilised by steam or, if of comparatively little value, destroyed by fire. If there is overcrowding of persons in houses, or of houses on space, these matters should receive attention. If cases tend to occur in the same locality it will probably be found to be an insanitary area requiring clearing and the consideration of a housing scheme.

J. C. T.

Under-drainage.—The object of under-drainage is to keep down the level of the subsoil water, so that the soil and the upper layers of the subsoil may be properly aërated and afford a proper feeding ground for the roots of the crops. The need for under-drainage is greatest with clays and heavy loams, and in districts with heavy rainfalls. Open sands and gravels, on the other hand, rarely require under-drainage; but when such land is to be irrigated with sewage or sewage effluent it should generally be drained. Various materials have been used for under-drains; unglazed earthenware pipes with butt joints being by far the best. The size of the pipes and their depth and distance apart will depend on the nature of the subsoil and on the rainfall. For stiff clays 2 in. pipes may be laid at a depth of 3 ft. and in lines 20 ft. apart, while in a gravelly subsoil 2½ in. or 3 in. pipes will be required at a depth of 5 or 6 ft., and at distances as great as 80 or 100 ft. In irrigated land the spacing will generally be closer, and the size of the pipes should not be less than 3 in. or 4 in. Larger pipes should, of course, be used for the mains. The pipes should be butted tight together, and in filling the trenches, especially in irrigated land, care should be taken to consolidate the material so that the water may not take a short cut through it from the surface down to the pipes. The neglect of this precaution in many cases has done much to bring under-drainage into disrepute.

A. J. M.

Underground Water.—Many towns depend for their water supplies upon subterranean sources obtained by means of sunk wells or borings. Such waters accumulate through percolation of rainfall into the "outcrop" of porous strata and often travel many miles underground until the lowest subterranean basin is reached. Almost any porous formation containing fissures or "vents" is capable of holding large quantities of water, especially when impermeable strata occur below. Good supplies are frequently derived from the chalk, new red sandstone, oolite,

magnesian limestone, Ashdown sands of the Hastings series, and other porous formations. It should, however, be understood that the quantity obtainable from any given strata varies considerably in different situations according as the rock into which the boring or well is sunk proves to be compact or much fissured. Chalk, for example, is one of the most favourable sources from which water may be obtained, but even this in some cases has proved to be so compact as to yield little or no supply. Briefly stated, the main conditions determining the quantity of water obtainable from subterranean sources are:—(1) The mean annual rainfall occurring over the "catchment area" feeding the underground basin, and the proportion thereof

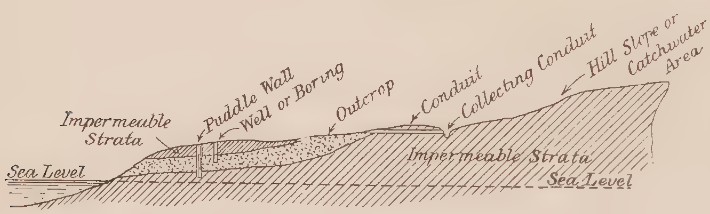


Fig. 1.—Conservation of Underground Water Supplies.

percolating in at the "outcrop" and ultimately finding its way to the subterranean store; (2) the extent of the outcrop of the water-bearing strata and the degree to which the slope of adjoining inpervious areas may contribute by conducting the rainfall falling thereon on to the porous outcrop; (3) the area of the underground contributing area or watershed; (4) the degree of porosity or permeability of the water-bearing strata, and the percentage of the total percolation which is again recoverable by means of pumping stations; (5) the extent to which artificial works may have been carried out for the purpose of retaining the rainfall upon the catchment area, and so preventing its rapid escape to streams and rivers, and the means adopted to intercept the flow of underground water into the sea or river-beds. Notwithstanding the fact that underground water is very largely used for purposes of public supply, but little attention has been given to the question of the conservation of subterranean water, probably owing to the fact that, in this country at any rate, underground storage is fairly regularly replenished by natural means before any very alarming depletion arises. It is also difficult in the majority of cases to locate, with a sufficient degree of precision, the most favourable site and nature of works likely to be effective. Where suitable conditions are known to exist, however, the quantity of water recoverable may be augmented by methods similar in principle to those illustrated in Fig. 1. Here an artificial dam or puddle wall is employed to intercept water flowing through permeable beds on its way to the sea towards which the water-bearing strata "dips." Water is also conducted on to the porous outcrop of the permeable strata by means of a conduit from an extensive catchment area or adjoining hillside. Much information as to the water-bearing capacity of any given locality is obtainable from a careful study of the detailed geology of the surrounding district. The most practical means of doing this is by first collecting particulars of all local borings or wells, the levels of the different strata passed through, and the rest and pumping levels of the water in such borings. These data should be utilised, with the assistance of reliable geological maps of the district, for the purpose of building up an accurate section of the strata in the manner illustrated in Fig. 2, which diagrammatically represents a case investigated by the present writer for public water supply purposes. The section covers a stretch of country about 14 miles in length, the surface levels of which were obtained from ordnance maps, whilst the levels of the different strata shown were derived from various borings, three of which are given in the figure. Upon carefully plotting to scale all available information and reducing all levels to ordnance datum, it was found the rest levels of water in all the borings coincided very closely,

showing the water-bearing sand-rock to take the form of a wide basin some 12 miles across, and to be uniformly saturated up to the level shown. The section also revealed the fact that a well or boring placed at *A* would be favourably situated for yielding a strong supply of water, which, on being tapped upon reaching the sand-rock at the depth of 200 ft. from the surface at once rose in the boring under an artesian head of 100 ft. The great importance of the study of practical economic geology has long been appreciated by the Geological Survey Office which has given much attention to the question of underground water supply, and has accumulated a large amount of information upon the subject. The data so collected is now being made accessible to the public by the publication of a series of "memoirs" dealing with the underground water supply and well borings of different counties, and the approximate yield available. Underground water is usually of great organic purity, but its composition naturally depends very largely upon the nature of the strata through which it has percolated. It is commonly highly charged with mineral constituents, and not infrequently of great "hardness," a large part of the latter quality oftentimes being "permanent." Very "soft" waters are also sometimes met with, and in some cases the supply will be highly charged with iron either in solution or suspension. For all these varying qualities appropriate means must be adopted to properly prepare the water for the ordinary requirements of domestic and trade supply.

W. H. M.

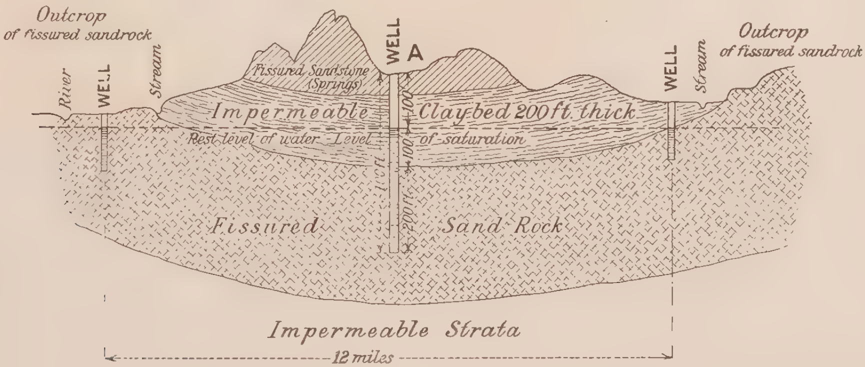


FIG. 2.—Section of Water-bearing Data, ascertained from Data on various Borings.

Urinals, Public. (*See* "CONVENIENCES.")

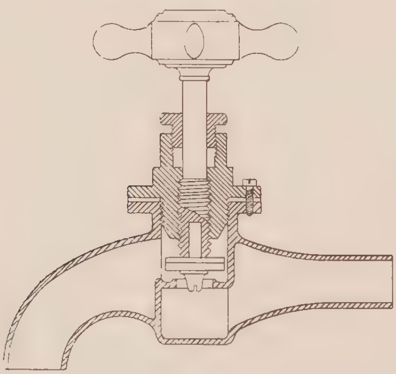
Urinals, amongst sanitary fittings, are the most difficult to keep in a wholesome condition owing to the urea contained in urine, which decomposes very rapidly, and the uric acid which, being but feebly soluble in water, is very liable to adhere to all surfaces with which it comes in contact. Even the best of these fittings are frequent sources of nuisance, and for this reason urinals are best avoided within dwelling-houses. Nor are they essential in such positions, as their place may well be taken by the water-closets. Where the necessity exists, only the most efficient fittings must be provided. The following conditions are essential in urinals :—(1) The soiling surfaces with which the urine comes in contact must be as small as possible consistent with convenience; (2) there must be an entire absence of angles, corners, and unevenness that would tend to retain deposits of urine or of dirt; (3) the materials of which the fittings are made must be smooth, impervious and incapable of being acted on by uric or other acids; (4) an abundant supply of flushing water applied each time the urinal is used; (5) thorough ventilation, abundant light, and

a cool atmosphere in the urinal apartment. (*See also* "CONVENIENCES, PUBLIC.")

Valves. (*See* "PUMPS.")

Valves (Water Supply).—Cocks or taps fitted with a loose valve or diaphragm acted upon by a screw spindle with handle or wheel. In screwing down the spindle, the valve is forced down upon its seating and the water gradually shut off. When unscrewed, the pressure of water forces the valve off its seat in some cases, while in others the spindle raises the valve, leaving the water free to flow through in either case.

Valves may be divided into "stop valves" placed on a pipe to regulate or shut off the



Screw-down Valve.

supply of water and "draw-off valves" made use of over sinks and other fittings for drawing water. A subdivision of the latter are "spring valves" so constructed that water can only be drawn when the valve is held open by pressure of the hand. When released the tap is closed automatically by a spring. Of these only those that close gradually and without concussion should be made use of when the water is under pressure. The spindles of all valves should be made of gun-metal, but all other parts may be of hard brass. The valves themselves must be fitted with washers of oil-dressed leather and for hot water with vegetable fibre of the best quality, unless they are metal-faced as in the case of Lord Kelvin's tap.

Varnish.—Considered generally varnish may be defined as being made from a fossil resin dissolved with heat in linseed oil or turpentine, but such a definition must necessarily be vague and there is no possible manner of specifying varnishes except by the name of the manufacturer or by the price. There are many grades of varnishes ranging from "white Coburg varnish" or "body varnish," costing from 24*s.* to 32*s.* per gallon down to the cheapest varnishes which may be had as low as 8*s.* per gallon, or less. The classification of varnishes in general is roughly as follows:—"white marble varnish," "white oil varnish," "white Coburg varnish," and "body varnish," "French oil varnish," "white copal," and the best "carriage varnish," range from 18*s.* to 24*s.* per gallon. "Maple varnish." "extra pale copal varnish," "flatting varnish," and "second grade carriage varnish," range from 12*s.* to 16*s.* per gallon. "Copal oak varnish" can be had at 10*s.*, and second grade of the same at 8*s.* Also may be added black varnishes or "Japans," as they are sometimes called, which are sold at from 10*s.* to 20*s.* per gallon, and are specially suitable for ironwork. Enamels come under the same category of varnish and vary very largely in quality, costing from 10*s.* or less to £1 1*s.* per gallon. (*See* "ENAMELS.")

Velocity of Flow. (*See* "FLOW IN PIPES.")

Ventilation of Buildings.—Amount of Air Required—Natural Ventilation—Artificial Ventilation—Cottages—Public Halls.—Pure air is as essential to human life as good food, although the fact is not fully appreciated, and before proceeding to deal with ventilation schemes it will be as well to study briefly the composition of the air.

The following table gives the proportions of an average sample of air taken by Parkes:—

Oxygen	.. .. ..	209·6 per 1,000 volumes.
Nitrogen	.. .. ..	790·0 " " "

Carbonic acid	0·4 per 1,000 volumes.
Watery vapour	Varies with temperature.
Ammonia	Trace.
Organic matter (in vapour or suspended, organised, unorganised, dead or living)	Variable.
Ozone	Variable.
Salts of sodium	Variable.
Other mineral substances ..	Variable.

Oxygen is the chief constituent of air, and the great purifier of air, as well as the principal aid in combustion. It is upon this gas that the heat and energy of our bodies depend.

Carbonic Acid.—Among the impurities in air this is probably the greatest. The late Sir Douglas Galton stated that 1·5 parts per cent. produce nausea, depression, and headache; 2·5 °/ₒ extinguishes a candle, and 5 parts per cent. is fatal. It will be evident from this that systems of ventilation must be such as will reduce this dangerous element to a minimum. The amount generally allowed as a safe quantity is ·6 per 1,000 cu. ft. The burning of gas in houses and factories is a great defaulter in polluting the air, and it has been found that 1 cu. ft. of gas will consume the entire oxygen of 8 cu. ft. of air, in addition to imparting impurities in the form of compounds of sulphur and carbon. The effect of impure air on the system is very detrimental, producing a lowering of the vital functions, and thus tends to the contraction of disease and prolongs the period of recovery.

Quantity of Air Required.—It has been found that an average adult gives off by respiration ·6 cu. ft. of carbonic acid (CO_2) per hour. By referring back to the table giving the composition of the air we find air contains ·4 cu. ft. of carbonic acid per 1,000 ft. By adding this amount to that given off by respiration a total of 1·0 cu. ft. of carbonic acid per 1,000 cu. ft. of air is obtained. This is more than has been laid down as the standard, viz., ·6 cu. ft. per 1,000 cu. ft. of air. The amount of air required per person per hour is 3,000 cu. ft., and the air of rooms should be changed with sufficient frequency, according to their size, to maintain that standard. This changing of the air is a matter requiring careful attention, in order not to give rise to draughts. Air which moves at a greater velocity than 2 ft. per second will cause draughts, and the system must be so arranged that this velocity will not be exceeded. The above amount of 3,000 cu. ft. of air per person per hour is an ideal state, and in practice it is found difficult to reach that standard. The usual amount in cottages is about 250 cu. ft. per person—*e.g.*, if we take a small room of 10 ft. by 10 ft. and 8 ft. high we get 800 cu. ft., but allowance must be made for furniture, which will occupy about 100 cu. ft., and if the room is occupied by three persons this gives 230 cu. ft. per person. The following table extracted from different sources, including the model by-laws of the Local Government Board, will give an idea as to what is generally required:—

Houses let in lodgings ..	150 cu. ft. per person under 10 years of age.
,, ,, ,, ..	300 cu. ft. for adults for sleeping only.
,, ,, ,, ..	200 and 400 cu. ft. respectively for rooms when not used for sleeping purposes.
Dairies, &c.	600 cu. ft. per cow.
Factories and workshops	250 cu. ft. per person.
,, ,, ,,	400 cu. ft. per person for overtime.
Schools (Education Department)	80 cu. ft. per head.[1]
Public Halls	1,200 - 1,500 cu. ft. per head.[1]
Hospitals (ordinary) ..	1,200 cu. ft. per head.[1]
,, (infectious) ..	2,100 - 3,000 cu. ft. per head.[1]

It is a mistake to imagine that lofty rooms take the place of air space. The amount of space available for ventilation purposes should be taken at a height of not less than 12 ft. and not more than 13 ft. There are two

[1] "Architectural Hygiene," B. F. Fletcher, p. 146 (1902).

methods of ventilation: (1) natural, and (2) artificial. It is proposed to deal with the principles and different appliances that are used in each system. It is impossible to carry out an efficient system of ventilation without having due regard to the allied questions of heating and lighting, and the reader is referred to the articles dealing with these subjects, as it is important to know how to utilise these two essential factors in any scheme of ventilation.

The forces which tend to move the air in rooms are two: (1) the wind, (2) the difference in temperature between the outside air and that in the room. The wind is a great factor in ventilation, and causes the air to move rapidly. Cold air is heavier than hot and upon entering a room falls to the bottom, displacing the hot air in the room. If the incoming air is unwarmed before it enters, it causes a draught and the inlet is closed by the occupants. The following table compiled by Scott & Co. gives the powers of fans manufactured by them, and will be useful:—

Foul Air extracted under Certain Heads of Water.

24 in. fan.				
Water pressure, lbs. per sq. in.	60	50	40	30
Air per min., approx. cu. ft.	4,000	3,000	2,000	1,000
Revolutions per min., approx.	500	350	220	150
Water per hour, gallons ..	120	100	60	45
¾ in. supply. 1¼ in. drain.				
18 in. fan.				
Air per min., approx. cu. ft.	2,000	1,500	1,000	800
Revolutions per min., approx.	650	450	300	200
Water per hour, gallons ..	90	60	50	40
½ in. supply. 1¼ in. drain.				

For many purposes water-driven fans would be unsuitable and electricity may be conveniently used. Messrs. Blackman make fans which are extensively used for this purpose, and for long buildings where the rooms are scattered and numerous, the "Guibal" type of fan appears to be the best.

Natural Ventilation.—This, as its term implies, means the conveyance of fresh air into the buildings by natural methods, such as ordinarily occurs through doors, windows, fireplaces, &c. As previously pointed out the forces necessary in this system are the wind and the difference in temperature, between the outside and the inside air.

Inlet and Outlet Tubes.—When bringing in the air by tubes, they must be arranged to have as few sharp bends as possible, as these greatly diminish the carrying power of the tube. Allowances must also be made for friction when calculating the size of the tubes to be used in the ventilation of rooms. They must be large, smooth inside, free from bends, and vertical and short as far as possible, and preferably circular in shape. The joints of the tubes must be thoroughly air-tight. The position of the openings must be carefully considered, as the cold air should not be allowed to fall directly into the room before it is slightly warmed. The height of air inlets above floor level generally adopted in practice is from 5 to 6 ft., preferably the latter.

The size of the inlets should be proportional to the number of persons occupying the room, and Dr. Corfield recommends that 24 sq. in. sectional area be allowed for each person. In calculating the sizes, the net opening only must be taken, and due allowance made for bars, &c., obstructing the opening.

Hood has given the following table for finding the sizes of the opening, taking into consideration the number of persons and lights, and size of the room:—

Size of Room.	Number of Occupants.	Number of Gas-burners.	Net Size of Ventilator.
10 ft. by 10 ft.	2 or 3	2	9 in. by 3 in.
16 ft. by 12 ft.	3 or 4	3	9 in. by 6 in.
20 ft. by 16 ft.	4 or 5	4	9 in. by 9 in.

The outlet must be in a high position, and as the warmest and foulest air is always at the top of the room, near the ceiling, the outlet should be in that position. The aggre-

gate area of the *inlets* should be somewhat in excess of that of the *outlets*, and the inlets should be placed as far away as possible from the outlets, so as to insure a thorough circulation of the air in the room.

System of Boyle's Ventilation for Infectious Hospitals. — Boyle's system of Ventilation for Infectious Hospitals, as described by the *Building News*, May 26th, 1899, is as follows :—

"This appliance, which Mr. Boyle has named 'Bactolite,' is intended to be employed in small-pox and other infectious-diseases hospitals . . . destroying the disease germs contained in the air of an hospital, as it passes, or rather is drawn, through an asbestos furnace situated in the roof, and connected with an 'air-pump' ventilator, effectually consuming the poisonous germs, and preventing them from passing into and contaminating the outer air and spreading infection.

"With the 'Boyle' system of ventilation, as applied to small-pox hospitals, the air inlets communicate direct with the external air through specially-constructed openings made in the walls, fitted with self-acting valves to prevent the air of the hospital passing by any chance out through these openings. The incoming air is warmed in cold weather to an agreeable and healthy temperature by means of Boyle's ventilating radiators, without the deterioration and discomfort which result from hot-air heating.

"Air Screens.—In warm weather, the fresh-air supply is cooled in its passage through adjustable refrigerating chambers attached to the radiators, and is washed and purified by filtration through saturated and medicated screens. The outlets and inlets are accessible in all parts for cleansing purposes. It would appear, from the tests which have been made by scientific experts, that air-screens are more effective when the air is drawn through at a low velocity by natural extraction than with mechanical propulsion. Sir Douglas Galton says: 'If air is forced rapidly through a screen, it cannot fail to carry dust with it.' Important features in the system are (1) the fresh air is brought directly into the room from the external air, there being no long, tortuous, and inaccessible channels to harbour dust and dirt; (2) the air supply not being overheated, its health-sustaining properties are unimpaired.'"

Artificial Ventilation.—This system depends for its working upon mechanical means for propelling air into, or extracting foul air from the room or rooms. It is divided into two systems, plenum and vacuum. The former method is that in which air is propelled into the rooms by fans or air pumps, thus forcing out the foul air. The vacuum system consists of extracting the foul air by means of furnaces, gas jets, fans, or exhaust pumps, and allowing the fresh air to enter to take its place.

With regard to the admission of the cold air from the outside, this should be brought in at a point above the people's heads and in an upward direction. It then becomes slightly heated before descending, but not warm enough to allow the already heated air to stay in the room.

The only methods which appear satisfactory in large buildings are those involving propulsion or extraction by fans. The air thus propelled should be first brought through a heating chamber if only for one room, and if for a number of rooms should be brought over a series of heated coils (*see* Artificial Ventilation below).

One of the largest installations of ventilation on the "plenum" system is that introduced into the Birmingham General Hospital, by Mr. Kenman, F.R.I.B.A., and is described in "Architectural Hygiene," by B. F. and H. P. Fletcher (1907), p. 189, as follows :—". . . . No fireplaces are used, the air being forced in by fans, cleansed, and brought to a proper hygrostatic condition by filtering through moistened screens, warmed when required by means of steam coils, and propelled through the wards into extract flues, whence it passes into the open through flapped and louvred openings, constructed so that the varying

movements of the outer atmosphere can exert no influence upon the outflow. . . . . The air is sucked in from windows in the basement (carefully selected so as to be out of the way of contaminated air) by a fan, passing first through a screen of strained cocoanut fibre, kept automatically wetted every quarter of an hour. The air is then carried through a series of horizontal steam pipes, heated to the required temperature, then through the fan and into the basement tunnels. These tunnels (or "ducts" as they are called) start in sectional area 11 ft. by 8 ft., and only in a few cases are they so little as 3 ft. in width at the extreme ends in a few branch ducts. From these ducts are taken the vertical ducts to the rooms above. At the mouth of each of these vertical ducts is a separate steam radiator to give extra warmth if required for different departments, in excess of that supplied by the main collection of steam coils." The foul air is forced into the outlet flues at the bottom of the room near the floor level. In the example above quoted, to insure success in the working of the scheme, all the windows are hermetically sealed. The reader may judge for himself as to the success after reading the following extract from an article in *The Hospital*, April 1st, 1899, commenting on a visit to the above hospital:—" . . . . The visit in question was paid with an open mind, and in conjunction with others anxious to observe in practice a previously carefully studied theory. . . . The point most generally commented upon was the apparently unnatural stillness of the atmosphere, whereas the air was being much more rapidly changed than is usual. . . . It seems that this subjective sensation is almost invariably experienced by newcomers to the hospital, though both nurses and patients gradually become accustomed to what scientists assert should be a natural (but which to most of us at present appears to be a somewhat artificial) atmosphere. It has been stated that this feeling of oppression does not meet with the entire approval of the visiting staff, as exercising upon them an indefinably depressing effect. The atmosphere of those wards visited struck the party as somewhat close, lacking in freshness. . . ."

The opinions of many authorities appear to be strongly opposed to propulsion of fresh air into rooms, and the following extract from a report laid before the United States Congress by the Government Commission on Ventilation will be of interest. "The relative merits of the upward *versus* the downward systems of ventilation may be estimated from the following considerations:—(1) The direction of the currents of air from the human body is, under ordinary conditions, upwards, owing to the heat of the body. This

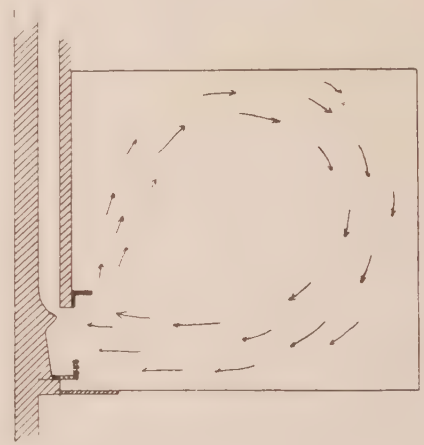


Fig. 1.—Movement of Air in a Room with ordinary Fireplace.

current is an assistance to upward, and an obstacle to downward, ventilation. (2) The heat from all gas flames used for lighting tends to assist upward ventilation, but elaborate arrangements must be made to prevent contamination of the air by the lights if the downward method be adopted. (3) In large rooms an enormous quantity of air must be introduced in the downward method if the occupants are to breathe pure fresh air, or about three times the amount which is found to give satisfactory results with the upward method. (4) In halls arranged with galleries, the difficulty of so arranging downward currents that, on the one hand, the air rendered impure in the galleries shall not contaminate

that which is descending to supply the main floor below, and, on the other hand, the supply for the floor shall not be drawn aside to the galleries, is so great that it is almost an impossibility to effect it. Perfect ventilation would not be obtained, for this would only provide for the dilution of the impure air, while in perfect ventilation the impurities are not so diluted, but completely removed as fast as formed, so that no man can inspire any air which has shortly before been in his own lungs or in those of his neighbour. For these and other reasons the Board are of opinion that the upward method should be preferred."

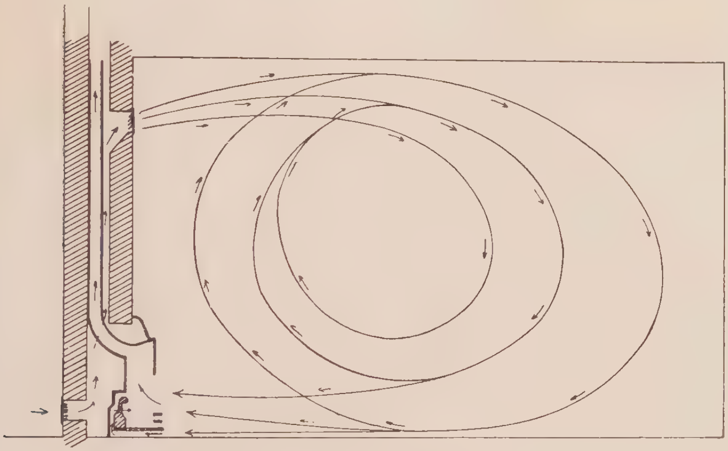


FIG. 2.—Movement of Air with Dalton's Fireplace.

Dr. John Hayward, in a paper on "Hospital Construction," read before the Liverpool Architectural Society on November 7th, 1898, also wrote as follows:—"To the plan of abstracting the foul air near the floor, there are at least four grave objections: (1) It is opposed to Nature's laws of atmospheric pressure, and therefore requires the use of special abstracting power by means of furnaces for its accomplishment. (2) By drawing down the foul air it causes it to be breathed over again, which recently breathed air ought never to be. (3) The fresh air supplied is apt to be forced in over-heated, in fact burnt, and so made unhealthy. (4) The long tortuous flues cannot be kept clean, and will therefore become lurking places for dust and germs. The plan is quite unsuitable for

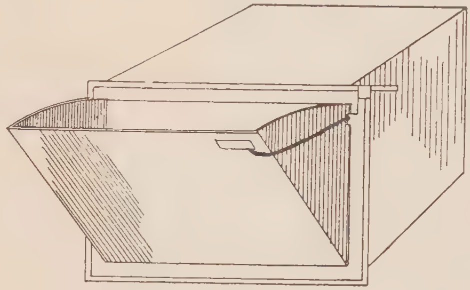


FIG. 3.—Sheringham Valve.

hospitals, and should certainly never be used where there is likely to be infection. Besides, it is also open to the same objections as ventilation by open fires, viz., that it tends to draw away the air of the lower part of the ward, where it is always the least impure."

PRACTICAL VENTILATION OF VARIOUS CLASSES OF BUILDINGS: COTTAGES.—Fresh air is generally admitted to cottages either by air-bricks or perforated gratings or other patent ventilators. These should be placed high up in the room. A flue may also be built in the chimney to admit the outside air and having an inlet for air into the room high up

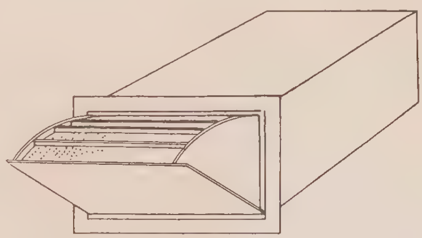


FIG. 4.—The "Leather" Inlet Ventilator.

in the chimney breast, the cold air thus being warmed before it enters into the room (see Fig. 2).

Public Halls.—The inlets for air may be of various kinds and shapes. Fig. 3 is an illustration of the Sheringham valve, and Figs. 4 and 5 are illustrations of an inlet valve patented by Mr. Leather, of Liverpool.

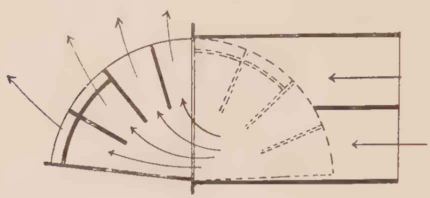


Fig. 5.—Section. Leather Inlet Valve.

It will be seen that the adjustable portion is divided into four compartments, two of which are covered by perforated zinc. Fig. 6 is an illustration of an inlet tube of the "Tobin" tube type. These are formed of boarding and lined with zinc, or made entirely of metal, having an adjustable part for regulating the supply of air. They are in some cases built in chases in the wall (see Fig. 7). Air may also be brought in over heating coils or radiators, thus being warmed before it enters the room (see Fig. 8). Extraction should be by means of a fan or an air-pump ventilator.

Fig. 6.

Factories and Workshops.—Ventilation in these buildings is comparatively an easy matter. There are, however, several important points to be borne in mind, and different methods must be adopted for different trades. Under the Factory and Workshops Act, 1901, bakehouses are classed as workrooms. It will be impossible to deal with every special trade and its requirements for ventilation, but a few will be touched upon briefly. The Factory and Workshops Act, 1901, gives the following air-space for the particular factories mentioned:—General Factories, 250 cu. ft. of fresh air per person; 400 cu. ft. of fresh air per person (overtime).

An Order gazetted February 11th, 1902, provides for: 600 cu. ft. of fresh air per person in humid textile factories (other than cotton cloth factories).

An Order gazetted January 1st, 1904, provides for: 500 cu. ft. of fresh air per person in underground bakehouses; 400 cu. ft. in bakehouses where work is carried on in artificial light other than electric light between 9 p.m. and 6 a.m.

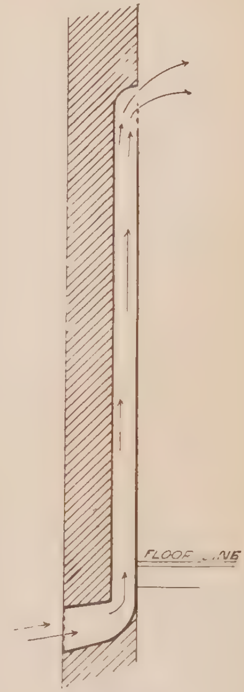


Fig. 7.

For cotton cloth factories, the Factory and Workshops Act, 1901, s. 94, states that ventilation shall be so carried out that during working

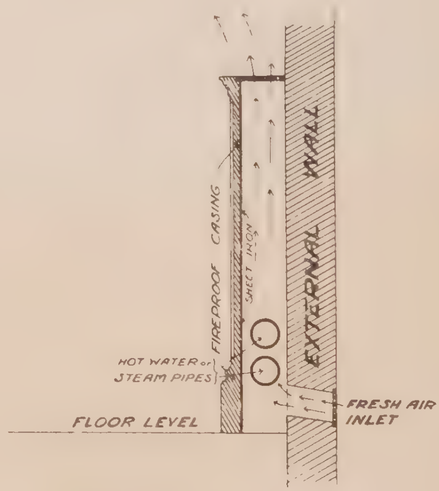


Fig. 8.

hours the proportion of carbonic acid in the air shall not be more than nine

volumes of carbonic acid to every 10,000 volumes of air. Strict enforcements are laid down for these and other humid factories with regard to temperature and moisture, and architects having these buildings to design and superintend should refer to the 1901 Act, s. 90. In factories where dust and other fine matter is produced as refuse from manufactured articles, arrangements must be made to extract it by means of exhaust fans, so that the fresh air coming into the workroom or factory will not scatter these particles about. All windows should have some portion made to open. Tobin or similar tubes should be fitted of sufficient size and number to convey the required quantity of fresh air according to the number of persons employed. If the air brought in must be warmed inlets should be made near the floor at the back of the steam warming pipes. These inlets should deliver air into a small closed-in chamber having a perforated cover or sides, through which the warm air will pass into the room.

Foul air may be extracted, at a point near the ceilings, either by means of an exhaust fan, or by openings made in the walls, covered by perforated cast-iron gratings, of the same size and number as the fresh air inlets.

R. H. B.

Ventilation (of Sewers and Drains).—The object of sewer ventilation is to regularly remove the gaseous impurities given off by the decomposition of sewage matters, commencing immediately upon their deposition, and to supply fresh atmospheric air from the outside. Sewer air ordinarily contains many impurities, amongst which may be mentioned a large proportion of complex hydro-carbon and nitrogenous vapours derived from decomposing animal and vegetable matters, considerable carbonic acid, ammonia, ammonium sulphide, sulphuretted hydrogen, and marsh gas. In the liquid sewage are large numbers of bacteria of various kinds, and these break up the organic matters into simple chemical compounds, and gases are evolved in the process.

The bacteriological contents of sewer air has been the subject of much careful investigation. The conclusions arrived at in 1893 as the result of an investigation on behalf of the London County Council were—(*a*) that the number of micro-organisms in sewer air is smaller than in the fresh air examined at the same time; (*b*) that the species of micro-organisms in sewer air are identical with those of fresh air, and not with those of sewage; (*c*) that moderate splashing does not influence the bacterial content of sewer air, even within 4 ft. of the disburbance; and (*d*) that stagnant and putrescent sewage does not influence the organisms in sewer air. The subject was further reported upon in 1894 by Dr. Andrewes and Mr. Laws, when they were unable, by means of the methods of research then available, to find any evidence that sewage gives up any of its bacteria to the air in contact with it. As a result of investigations made up to that period, the opinion had become general that under ordinary conditions sewage does not contaminate the air with which it is in contact with its own specific bacteria, but the improvements which have more recently been made in the technique appropriate to an inquiry of this kind has now warranted a modification of these opinions. Dr. F. W Andrewes in his "Report on the Micro-organisms present in Sewer Air and the Air of Drains," which appears among the appendices of the report of the medical officer of the Local Government Board for 1906—07, says, "Under certain circumstances, at all events, sewage gives up its bacteria to sewer and drain air. Such bacteria may form but a small proportion of those present in sewer air: this is likely, for they would not otherwise have escaped detection by previous observers. But it is probable that the circumstances under which sewage gives up its bacteria are common and ordinary circumstances in sewer and drain construction, for the employment of selective culture media has enabled me to discover them wherever so far

looked for in the air of drains and sewers. . . . The importance of the subject is plain, for though the organisms which I have been able to detect in sewer air are not in themselves known to be prejudicial to health, being for the most part well-known saprophytes of the normal alimentary tract, yet their value is evident as indices of the possible presence of more harmful sewage-borne microbes."

The typhoid bacillus does not thrive well in sewage, and their death is probably only a matter of a few days, or at most one or two weeks. Prolonged inhalation of sewer air may prove injurious to health by lowering the vitality of the human system and so predisposing to disease; hence the importance of keeping the air from sewers and drains out of inhabited rooms, both by adopting sound sanitary arrangements and also by thoroughly ventilating dwellings by making provision for a constant circulation and change of air.

One of the most effectual means of keeping the air of sewers as pure as possible consists in laying the sewers at self-cleansing velocities, and in maintaining a clean and smooth bore. In this way the sewage passing through them away to the outfall expeditiously minimises the opportunities for decomposition, and the sewers are kept free from bad air. As soon as septic action sets in offensive gases are evolved, and the air of sewers becomes very foul.

The principal methods which have been adopted for the ventilation of sewers may be shortly summarised as follows:—

(*a*) Natural ventilation by the aid of open surface gratings at the road level, assisted by iron ventilating columns erected along the line of sewers, or by carrying ventilating shafts up the flank walls of buildings and other available places.

(*b*) Mechanical ventilation, by means of powerful fans.

(*c*) Heat extraction, such as by—

(1) Connecting sewers with chimney shafts.

(2) Connecting with iron on other shafts erected along the lines of sewers, each of such being provided with heat either by a gas-burner in the base of the column or by means of a gas jet at the top—the object being to create an upward draught.

(*d*) Deodorisation of the sewage and sewer air by the addition of disinfectants, chemicals, &c.

Natural Ventilation of sewers depends upon the same laws as those which govern the circulation of air in buildings, and is the system most generally relied upon. Movement of the air depends upon the differences of temperature between the inside and outside of the sewers, upon the outside wind currents setting up aspirating or extractive effects by blowing across the tops of ventilating columns, manholes, and other openings, also upon the variations of flow in sewers and the consequent displacement of air. The conditions of the atmosphere, wind, &c., largely influence the working of natural systems of ventilation, hence it is frequently found that columns, unaided by heat or other artificial force, are inoperative, and occasionally observed to be passing a current of air in the reverse direction to that intended. Ventilation shafts, when sufficiently numerous, afford useful points of relief of pressure within the sewers, especially in hilly districts where the sewers become rapidly charged and either force through or siphon out the traps on house drainage systems. Street columns are usually spaced from 100 to 200 yards apart and especially at the high or dead ends of sewers where they give the best effect. The shafts should be from 20 to 30 ft. in height, and preferably not less than 9 in. in diameter, to prove of any considerable ventilating efficiency. Shafts placed up the side walls of houses are usually much less effective owing to the number of bends occasioned in the fixing, and to the occasional overshadowing of the tops of the shafts by roofs of surrounding properties. Every right-angled bend reduces the ventilating effect by about one-fourth. Rust and dirt also accumulates at the bends, which in time seriously reduces the efficiency of the ventilator. The thorough ventilation of large mileages of sewers is a matter of some considerable difficulty, and whatever system is

adopted, it should be simple and free from all complicated apparatus and independent, as far as possible, of mechanical aid. This simplification is necessary in order that the cost of installation and of annual maintenance may be confined to within moderate limits, otherwise the system could not be reasonably extended over large areas. The direction of sewer air-currents varies with the position and direction of the lines of sewers with relation to the prevailing winds. In hilly districts the sewer gases tend to accumulate in the higher parts, unless checked in short sections, as is sometimes the case, by means of ramps or drop pipes fitted with flaps, so that any gases accumulating in each section may be separately dealt with, instead of traversing the whole length and rise of the sewer. The accumulation of sewer gases at the upper, or their fall to the lower, parts of a sewerage system necessarily varies from time to time according to the relative specific gravities of the gases or air currents which obtain at any given moment.

Heat Extraction of sewer gases is a good method of ventilation if employed under proper safeguards, and when it can be installed without involving an excessive initial outlay and subsequent heavy maintenance costs. The use of gas-heated ventilation columns involves a heavy annual expense amounting, very usually, to from £12 to £15 per year, and, as the number of such columns in even a medium-sized town may need to be over a hundred it will be seen that a serious yearly expense is entailed. It should also be remembered that accidents occasionally arise in the combustion of sewer gases, which sometimes contain explosive mixtures, such, for example, as when a leakage of coal gas gains access to the sewers. The connection of sewer ventilation pipes to tall chimney shafts also involves considerable risk of dangerous explosions, and so is now seldom adopted.

Mechanical Ventilation has been tried in many different forms, principally by the application of fans, but the effect of these is discernible only over very short lengths of sewer, and, moreover, is readily overpowered and counteracted by wind currents and natural differences of temperature. Heavy initial outlay, running, and maintenance charges are an effectual bar to the wide adoption of this means of ventilation.

In deep sewers it is frequently necessary to propel air into the sewer at one end and to extract vitiated air from the other by means of large fans driven by motive power.

Deodorisation is not properly speaking a system of ventilation, inasmuch as it does not remove the foul and introduce fresh air, but simply relies upon the covering, disinfection, and deodorisation of offensive gases emanating from sewage. Care is required as to the kind of deodorants or chemicals used as their employment affects the final treatment of the sewage at the outfall works. The cost of chemicals and the necessary attention to their application renders the process too expensive for wide application, although it may be useful in certain special cases.

Examination and Entry of Sewers.—The condition of the air in sewers requires careful testing, especially in the case of deep sewers, before workmen should be allowed to enter. This is most conveniently done by first lowering a lighted candle; if the light goes out or burns dimly the sewers should not be entered until thorough ventilation and change of air has been effected, and the conditions of the atmosphere of the sewer again tested by means of a light. Should there be any sign of explosive gases, "safety lamps" should be used. In the present days of the very general employment of motor-cars and the consequent extended use of petrol, it is found, as a matter of experience, that this inflammable liquid often gains access to the sewers, by accident or otherwise, so that increased care of entry and the use of covered lights is essential.

W. H. M.

Venturi Meter.—This is a very useful apparatus for the measurement of large volumes of water, such as are passed through a rising main, leading supply pipe, or delivery

pipe from filter beds. The meter consists of two parts, the tube and the recording apparatus. The tube is fixed within and forms a part of the ordinary pipe line, and only differs from it by presenting for a short distance a truncated reducing cone coupled by a throat-piece to a similar expanding cone (see Figure). These reducing cones form the Venturi tube, and there are thus no moving parts in contact with the water. The measurement is obtained by the application of the Venturi law, that water flowing through a pipe of diminishing area loses lateral pressure as it gains in velocity. The difference in pressure thus obtained between the up-stream end of the reducing cone and the "throat" is termed the "Venturi head," and, as the velocity in the pipe is proportional to the square root of this reduction of pressure, the velocity and thence

Venturi Meter.

the rate at which the water is delivered through the pipe is inferred as a question of hydrodynamics. The observed reduction of pressure caused by the contraction of the pipe is conveyed by two small tubes (shown in Figure) to the recording apparatus which may be fixed anywhere within 1,000 ft. of the tube, or, if so desired, the registration may be conveyed electrically to any distance. The recorder is a somewhat complicated apparatus, consisting broadly of a mercurial U tube receiving and embodying the element of the Venturi head, and of appropriate clockwork and gear which supplies the element of time, for the purpose of automatically recording the rate of flow upon a revolving diagram and exhibiting upon a counter the total quantity of water passed.

Vital Statistics.—The science of statistics involves the collection of individual facts, with the view of grouping them into different classes according to certain definite characters they possess. These dividing characters must be constant, and must be definite. The uses of vital statistics are to obtain information as to the health of the people, as to the various diseases from which they suffer, to assist in the study of the good and evil conditions affecting humanity, and to furnish the necessary data for life assurance. For the purposes of vital statistics it is necessary to have a correct enumeration of the population (*see* "Population, Enumeration of"), and a complete and accurate registration of births and deaths; and when conclusions are formed and comparisons made it must be borne in mind that the likelihood of accuracy increases as the square root of the number of units dealt with. Annual death-rates, birth-rates, and marriage-rates are generally expressed as so many deaths, births, or marriages among every 1,000 of the living population; they are, therefore, obtained by multiplying the number of births, deaths, or marriages during the year, by 1,000, and then dividing by the number of the population. If the period for which a birth or death-rate is calculated is less than a year, the rate then indicates the number of births or deaths per 1,000 of the population that would take place in the year if the proportion of births or deaths recorded during these shorter periods were maintained throughout the year. Thus a monthly death-rate would be calculated by taking the deaths registered during four weeks, multiplying these by the thirteen four-weekly periods in the year, and then multiplying by 1,000 and dividing by the number of the population. Now the proportions of children, middle-aged persons, and old people to the total population may vary in different communities, and as the death-rate varies at different ages of life, and even between males and females at the same ages, a correction must be made for any differences in the age and sex distribution before it is fair to com-

pare the general death-rates of two towns. The means of obtaining the factor or "figure for correction" is fully described in the Annual Summary of the Registrar-General for the year 1883, and the lengthy procedure is outlined in most text-books of hygiene and public health. The multiplication of the recorded death-rate of the district by this factor gives the death-rate which would obtain in that district if the sex and age distribution of the population of the district were in the same proportion as it is in the country as a whole — thus eliminating the accidental differences due to sex and age, and affording a fair means of comparison of the healthiness of the district. It is obvious that the factor for correction can only be calculated when the precise age and sex distribution of the population has been recently revealed by a census. There are other precautions which must be taken in order to avoid unfounded and erroneous statistical deductions. The number of deaths, for instance, at a certain age-period must be expressed as the proportion of the number living at the age in question, this number as we have seen varying considerably in different communities; moreover, a special disease may be one mainly affecting certain age-periods, and a like error will be involved if the rate is not expressed as per 1,000 of the population living at the same ages, and of the same sex, as those attacked. Therefore it is a general rule in calculating death-rates that when the disease affects only a particular section of the community it should be expressed as the rate of mortality to every 1,000 of those who are liable to contract the disease. A good illustration of the application of this principle is to be found in the puerperal fever death-rate, which is taken as the ratio of the deaths from puerperal fever to every 1,000 registered births, since only those females who have recently been delivered of a child are liable to die from this complaint.

Mild winters and cool summers favour a low death-rate from the lessened mortality from respiratory diseases and certain intestinal diseases. The best statistical evidence of the health of the community is furnished by the corrected death-rate, although a sick-rate, were it available, would furnish still better evidence. The zymotic death-rate also affords valuable evidence of the sanitary circumstances of a community. The zymotic death-rate represents the proportion of deaths from the seven principal zymotic diseases to every 1,000 of the population. The seven zymotic diseases recognised by the Registrar-General are:—Small-pox, measles, scarlet fever, diphtheria, whooping-cough, "fever" (namely, typhus, enteric, and simple continued fevers), and diarrhœa. Of these enteric fever and diarrhœa are more particularly associated with insanitary surroundings. The death-rate from consumption is also evidence of certain insanitary conditions of housing and of occupation; and the rate of infantile mortality also ranks high as evidence of the health of the community. With reference to this latter rate it must be pointed out that an infant is taken to be a child under one year of age, and the rate is therefore expressed as the proportion of deaths under one year of age to every 1,000 registered births. A life-table is a very valuable means of comparing the vitality of a community at one period with that of another period or with that of another community. By furnishing, by the law of probability, the expectation of life of the different members of the community, it supplies a valuable comparative figure for statistical purposes, and one which, by enabling us to measure the probability of life and death, affords a scientific basis on which the calculations for life assurance are based. A life-table represents a generation of individuals passing through life to extinction; and the calculations of a life-table relate to an arbitrary number of individuals supposed to be born simultaneously, and to exist under the same conditions as those which apply to a general community. Usually the population is assumed to start with 1,000,000 births, and these are divided into males and females in proportion to the actual number of births of

either sex that have occurred in the given community during an inter-censal period of 10 years. The mathematical probability of survival of every individual for each year of life is then calculated from data obtained from the actual community, and thus the hypothetical life-table population becomes the medium for the record of facts concerning the vitality of a given population. By the English table for 1881—90 the expectation of life at birth, for males, is 43·66 years; whereas amongst females the expectation of life is 47·18. For the purposes of comparing occupational mortality, the death-rates amongst those employed in different occupations must be severally compared with the death-rate for England and Wales for the corresponding age periods and sex. In that way "a comparative mortality rate" can be obtained.

The Chief Vital Statistics of England and Wales for the Year 1907.

The general death-rate	15·0*	per 1,000 per annum.
The marriage-rate ..	15·8	,, ,,
The birth-rate ..	26·3*	,, ,,
The phthisis death-rate	1·14	,, ,,
The zymotic death-rate	1·26*	,, ,,
The scarlet fever death-rate	0·092*	,, ,,
The enteric fever death-rate	0·067*	,, ,,
The diphtheria death-rate	0·164	,, ,,
The measles death-rate	0·361	,, ,,
The whooping-cough death-rate	0·293	,, ,,
Diarrhœal diseases death-rate	0·305*	,, ,,

The rate of infantile mortality was 118* per 1,000 registered births.

* The lowest on record.

H. R. K.

Wanklyn & Cooper's System of Sewage Purification was proposed in 1899, and consists of a system of aëration with continuous flow through a series of tanks. The aëration is aimed at by the application of means for continually removing the top layer of liquid and placing that layer down at the bottom of the next tank in the series. The sewage has to be elevated to give a fall of 7 ft., thus providing for a drop of about 4 in. between each of the series of tanks.

Waring System of Sewage Treatment.—Colonel George Waring obtained permission in 1894 to treat a portion of the sewage of Newport, Rhode Island, and there conducted experiments with the view of dealing with a large volume of sewage with a given tank capacity by means of a continuous system of working assisted by forced aëration. The Waring system differs from Lowcock's method (*see* Lowcock's Filters) principally in regard to the separate treatment of the sewage sludge by the employment of aërators. The sewage first passed a settling chamber for the removal of road grit, thence through a shallow bed of coarse broken stone to take out the coarser solids, and following this through "straining tanks" containing stones and gravel with the object of effecting a mechanical sedimentation. The sludge from the latter when requiring emptying passed into a separate aërating tank again containing stones and gravel, where air was constantly forced through the material and the sludge dissolved by bacterial action. The straining tank was also rendered fit for re-use by forcing air through. Since the first experimental work there have been alterations of detail, and installations have been carried out at Willow Grove Park, Philadelphia, East Cleveland, Ohio, and many other places in the United States.

Wash-Houses, Public.—Acts of Parliament.—Power to erect Public Wash-houses is contained in the Baths and Wash-houses Act, 1846, and the subsequent Amendments of 1847 and 1882. These sections also provide that the proportion of second-class washing accommodation shall be equal to twice the accommodation of the first-class (if any), and the maximum scale of charges are also set forth.

General Consideration.—When considering the question of a Public Wash-house, account must be taken of the neighbourhood,

whether it is advisable to combine this provision along with the swimming and slipper baths. Should the locality where the swimming baths, &c., are to be provided be somewhat of a superior character it may be desirable to build the wash-house separate and erect it in an industrial locality. An isolated building will be much more expensive to administer, but may be more convenient to the users. If the wash-house is erected along with the whole system of the baths, the entrance should be set in a side or back street so as to be away from the traffic and not interfere with the main entrance to the swimming and slipper baths.

Entrances, &c.—Immediately inside the entrance door there should be a way into a covered forecourt where the women may leave their perambulators, mailcarts, &c., used for carrying their washing, until they return home. Arrangements should then be made for the washers to pass a barrier with their bundles, obtain their tickets from the office, and await their turn in a waiting room.

Ticket Office.—This should be so arranged that the clerk may control the women's second, (and perhaps the first) class slipper baths, if possible, at the same time as the wash-house. In this case the first-class bathers would pass on one side of the office and the second-class and the women washers on the other. This will depend, however, on the amount of business done—should the number of washers be large it may result in a ticket office being required exclusively for the wash-house.

Waiting Room.—The waiting room should have lockers for the women, and a table, &c., for partaking of refreshments, as well as an open fireplace where water may be boiled.

Washing Room.—The washing compartments, which generally number about 50, should be arranged on either side of a central division with the supply pipes running over the partition. All iron should be galvanised. There should be three troughs, one each for boiling, washing, and rinsing or blueing, and a shelf on top for soap, &c. The troughs are generally of iron, but occasionally are of porcelain. In the former case they are removable for cleansing purposes. If the compartments are arranged on either side of a central division and the washers in two rows side by side, each compartment will occupy a space 4 ft. long by 3 ft. 6 in. deep. The compartments are, however, sometimes ranged on either side of a central division, but the troughs are placed in pairs at right angles to the partition. This is a much more expensive method, but it allows the drying horse to be arranged parallel to the system, and permits each washer to see her clothes horse. The partitions between each compartment are about 5 ft. high and are solid only down to within 2 ft. of the ground. Ample space must be allowed for washing down by the staff and the free use of a broom. A continuous slatted foot-board should be provided for the women to stand on while washing. Particular attention must be given to the question of drainage, so that the waste water may be quickly carried off and any stoppage readily removed. In the same room and in close proximity to the drying horses there should be two or three hydro extractors which answer the same purpose as a wringing machine. Care must be taken to make the belting safe so as to avoid accident. There should be a folding table in the wash-house, also hat and coat pegs for the women. The drying horses should be placed at right angles to the troughs so that each woman may be able to stand sideways to and watch for the safety of her clothes when they are in the drying horse. There should be at least one horse for every washing compartment, and, if possible, one or two to spare in case of a breakdown. The horses are generally 6 ft. 6 in. long by 6 ft. 6 in. high and 12 in. on face, hung entirely from a top rail so as to avoid grooves in the floor. Each horse should have four or five pairs of clothes rails, and there should also be a thin sheet iron plate dividing one horse from another as it prevents a recently wet article communicating its dampness to an almost dry garment. It also prevents theft by transferring articles

from one horse to another when one of the horses is partly withdrawn. The heat is conveyed from a small coil chamber and driven forward by a fan along a 1 ft. 6 in. by 9 in. iron duct, having an outlet hole over each compartment, the hole being automatically closed when the horse is withdrawn. The horse has also a door at the back, corresponding to the front one, to close the chamber when the horses are out, and so prevent the hot air from escaping. There should be plenty of top light and a Blackman fan in the gable to extract the steam which usually fills the room. W. C. accommodation should be provided immediately out of the wash-house room. Adjoining the washing room and near the waiting room and entrance there should be placed the mangling and ironing room, fitted with ironing and folding tables, stove, and one or two box mangles, mechanically and continuously worked. These mangles usually measure 10 ft. by 4 ft.

Artificial Lighting.—The artificial lighting of the premises should be by electricity, if possible, but a light should always be placed in front of each trough. R. J. A.

Waste-Pipes. (*See* "Plumbing.")

Waste Preventers.—Cisterns for flushing closets and other sanitary fittings, arranged to discharge a limited quanity of water at each flush. The quantity of water permitted to be used by the majority of water companies is 2 gallons for each discharge. Where no such restrictions apply a 3-gallon flush is desirable. Flushing cisterns of this nature are generally actuated by a chain, which when pulled either admits water to the long leg of the siphon in the cistern or forces a body of water over the bend of the siphon and brings about the discharge of the cistern. The details of construction in the working parts of the cisterns vary greatly, but all depend upon one of these two principles; simplicity of mechanism is always an advantage.

Water Analysis.—**Microscopical Examination—Chemical Examination—Chlorides—Hardness—Ammonia—Oxidised Nitrogen—Nitrites—Poisonous Metals—Phosphates—Organic Matter—Interpretation of Analysis.**—Water is usually analysed to ascertain its fitness for drinking and other domestic purposes. It is also examined to determine its suitability for use in steam boilers, and for special manufacturing purposes. In the sanitary analysis of water a point of great importance frequently lost sight of is that the analyst is, except in the comparatively rare cases where the water contains a poisonous metal, not engaged in seeking for the actual substance that may do harm to the consumer of the water, but in estimating small quantities of substances that are found by experience to be the usual concomitants of polluting matter which may contain harmful bacteria. Such substances are present in varying amount in drinking water from most sources, and if an analyst is examining a water for the first time, and without any knowledge of its derivation or surroundings he cannot so surely certify its purity as when he possesses such information.

It is by the periodical examination of a water that the most useful information can be obtained, as any influx of polluting matter is almost sure to be detected by a careful microscopical, chemical, and bacteriological examination. Sometimes, from motives of economy, water supplies, whether public or private, are examined very seldom, or not at all. In other cases periodical examinations are made and the more frequently and minutely this is done the sooner any variation in the water will be detected and the cause ascertained. It is highly desirable that all waters should be submitted to all three methods of examination. The microscopical examination possesses the advantage of rapidity, and in some cases the actual cause of trouble and the spot where it takes place can be ascertained more quickly than by any other means. The chemical examination has the great advantage that it is less liable to accidental fluctuations than the bacterial con-

tents of a water, and that the chemical bodies that accompany or are generated by pollution remain to some extent in the water and indicate that undesirable matters can gain access to the water, even if the bacteria which accompanied them are no longer present. The chemical data yielded by a water are governed by the strata through which or over which the water flows, whether the gathering ground is cultivated or not, by the rainfall and the temperature. Thus water collected from chalk or limestone will contain carbonate of calcium; water from a ferruginous formation may contain iron, and waters from peaty ground vegetable acids.

The bacteriological examination of a water has the advantage of affording a test which in many cases is of greater delicacy than chemical analysis. It has repeatedly been shown that an exceedingly small quantity of polluting material (sewage for example) may be added to an otherwise pure water, which, though incapable of detection by chemical means, can be detected with ease and certainty by a bacteriological examination. The fact that it is not often possible to detect specific bacteria, such as the bacillus of typhoid fever in an actual water supply, does not detract seriously from the usefulness of a routine bacteriological examination, when we are able to detect variations in the number and character of the bacterial population, which are greater than can be accounted for by any alterations of temperature or other normal causes. (*See also* "Water, Sampling of.")

The Microscopical Examination of Water.—It is necessary in the first place to draw a distinction between waters that have been filtered, either naturally or artificially, and those that have not. For instance, an upland water that has been artificially filtered through sand, or a chalk water that has been naturally filtered, ought both to be almost entirely free from visibly suspended matters, while an unfiltered river water of good potable character may contain a considerable number and variety of organisms and other suspended matters without any suspicion being thereby caused. The various organisms found in waters are usually shown in text-books on water analysis. Many of them have no hygienic significance at all, and simply afford evidence that the water has been exposed to air and sunlight and are found in pure mountain streams—some of them when present in quantity may produce an unpleasant smell or taste in the water, or may tend to act on the mains, or even produce such prolific growth as to diminish their capacity. On the other hand, microscopic examination may reveal the presence of starch granules, undigested muscular fibre, epithelial scales, fibres of paper, or fibres of clothing. The presence of these would naturally require explanation, and would cast grave suspicion on the water. In addition to the above the presence of such organisms as the sewage fungus (*Beggiatoa alba*), rotifers, or paramœcia would be regarded as suspicious. To examine a water for suspended matter it is usually customary to invert the bottle containing the sample in a conical medicine glass and allow the suspended matter to settle as far as possible in the bottom of the glass, from which it is subsequently drawn up by a pipette in a few drops of water and examined on a slide under the microscope. Most of the objects likely to be present can be discerned without staining; but after an examination it is advisable to add a little solution of iodine in order to decide whether any starch granules are present or not. The slide or slides should be examined under a $\frac{2}{3}$ in. and also under a $\frac{1}{6}$ in. objectives. With the latter it is frequently possible to see bacteria, particularly the motile forms, without having recourse to staining. Some of the suspended matters commonly found in water do not readily settle to the bottom, and a good plan is to employ a method of filtration such as that proposed by Dibdin, or the original method of Sedgwick and Rafter, or its modifications. By means such as these it is possible to obtain a more or less accurate idea of the quantity of suspended matter present, as well as to ascertain its character. In the physical examination of a

water, particularly when periodical examinations are to be made, it is an advantage to record its colour. This can be conveniently judged and recorded by using Lovibond's tintometer—an apparatus in which a definite depth of the water is examined in a tube and its tint imitated by comparing it with slips of colour-glass of standard tints. The tinted glass slips are numbered, and in this way a definite record in figures of the tint can be obtained for future comparison. Since any variation in the composition of a water is very likely to be accompanied by a change of colour capable of detection by this apparatus, it is deserving of more extended use. Such an apparatus if regularly employed to make a daily test at a waterworks would be a useful means of giving an immediate warning of a change in the water that might otherwise escape notice. Generally speaking, the purest waters possess a faint blue colour. River waters and upland waters may have a greenish tint, while a yellowish colour would be suspicious, though peaty waters may have a brownish tint. The standard glass slips of the Lovibond tintometer are coloured red, blue, and yellow and hence not only can any tint be matched by the use of the various glasses, but the degree of turbidity can also be recorded. The smell of a water is usually recorded as "normal" or "abnormal." In some cases the growth of various algæ may produce a noticeable smell; but it is very unusual to find any water otherwise fit to drink possessing any distinct odour. The only exception to this rule is the case of some peaty waters. The best way to ascertain whether a water has smell is to place about 200 c.c. in a stoppered bottle, warm up to about 65° C., shake, and then remove the stopper, and smell immediately.

Chemical Examination of Water. — The general method of procedure adopted by most analysts in this country is modified to suit individual cases; but the ordinary practice is to determine the following items, viz., the solid residue left on evaporation, and its "loss on ignition," the chlorine, nitrates, saline and albuminoid ammonias, the oxygen consuming power, the hardness, temporary and permanent, and the presence of nitrites and phosphates. These data are usually sufficient in the case of a potable water. In the case of water for steam-raising, it is necessary to perform a mineral analysis of the solids because on the amount and character of these will depend the quantity and character of the "scale" likely to be formed in the boilers. The total solid residue is estimated by evaporating a known quantity of water in a platinum dish, over a small naked flame to a low bulk, then finishing the evaporation on a water-bath, and finally drying till constant in weight in an air-oven at 105° C. As the solids absorb moisture very readily they must be dried with care, cooled in a desiccator, and weighed quickly. After weighing, it is customary to ignite the solids carefully by heating them in the same dish. Very useful information can often be obtained by the appearance and smell of these solids on ignition. Distinct odours of either vegetable or animal matters are often obvious, or a perceptible darkening owing to the carbonising of organic matter may be noticed. The ignition should be carried to such a point that all organic matter is burnt off, but at a sufficiently low temperature as not to cause the volatilisation of chlorides. After ignition the solids are moistened with a strong solution of ammonium carbonate and again very gently ignited. This re-converts the calcium carbonate that may have been rendered caustic by the first ignition into carbonate again. The weight of the ignited solids subtracted from the total solids is reported as "loss on ignition." The amount of total solids varies from a grain or two per gallon in rain-water up to 80 or 100 grains in some waters which are fit to drink. River waters may contain from 5 to 30 grains per gallon; chalk waters from 20 to 40, and upland waters from 10 to 20.

Chlorides.—A very low figure for chlorides is good evidence of the purity of a water, for the reason that sewage contains urine which

itself contains a constant amount of sodium chloride. On the other hand a water may contain several grains of chlorine per gallon and be perfectly free from pollution, the chlorine being derived from the geological formation. As might be expected, wells near the sea are often high in chlorides. If the figure representing chlorine is known for the particular formation from which a water under examination is derived, then any increase on this would be highly suspicious. In countries where the geological structure is continuous over wide areas, it has been found useful to prepare maps indicating the distribution of chlorine (*isochlors*) and though in small insular countries like England this plan cannot be adopted over large areas, there are districts where the purest waters give a constant figure. The estimation of chlorides is carried out by titrating a measured quantity of the water with a standard solution of silver nitrate, using potassium chromate as an indicator. It is necessary that the water should not be acid.

THE HARDNESS of a water, or its soap-destroying power is due principally to the lime-salts it carries in solution. The hardness of a water is composed partially of salts precipitated by boiling (temporary hardness) and of others which are not so removed (permanent hardness). The temporary hardness is due to calcium carbonate, held in solution by dissolved carbon dioxide, and is nearly all removed by boiling, which by driving off the carbon dioxide causes precipitation of nearly all the calcium carbonate. Water derived from chalk and limestone naturally contains calcium carbonate, while in water from the greensand calcium sulphate predominates. Water containing calcium carbonate is softened on the large scale by adding known quantities of milk of lime, sufficient to neutralise the dissolved carbon dioxide. This produces a precipitate of calcium carbonate, which in many cases is dried and sold if of good colour. The precipitate is allowed to subside, or the treated water is filtered through cloth and comes out clear and brilliant. Permanent hardness is not affected by the addition of milk of lime, or may be slightly increased if the lime used contains any sulphates. There are a variety of patterns of self-acting apparatus sold for the purpose of adding regulated quantities of milk of lime to the water to be softened. The milk of lime must not be in excess, and it is customary to test the purified water with a solution of silver nitrate, which yields a brownish tint if too much lime has been added. The hardness of a water may not be entirely due to the carbonate or sulphate of calcium, as calcium nitrate or magnesium salts may also be present. In the laboratory the hardness of a water is usually ascertained by the use of soap-solution. This is prepared by dissolving 10 grammes of Castile soap in methylated spirit and making up to 1 litre. This solution is then standardised against a standard solution of calcium chloride made by dissolving 1 gramme of Iceland spar in as little hydrochloric acid as possible and carefully evaporating twice to dryness, afterwards dissolving in distilled water and diluting to 1 litre. The soap solution is either diluted with more spirit or strengthened (by adding more soap), until 11 c.c. of soap produce a lather lasting about 2 minutes, with 10 c.c. of the standard calcium solution, when diluted with 60 c.c. of distilled water. The mode of using the soap solution is as follows :—70 c.c. of the water to be tested is placed in a bottle capable of holding about 200 c.c. and soap solution is run in from a burette about a c.c. at a time, with occasional shaking. As soon as there is any appearance of a froth forming, half a c.c. is added at a time, and when a lather forms that lasts about 2 minutes the volume of soap solution used is noted, and 1 c.c. is deducted for the amount of soap that would have been required to make a lather if there had been no hardness at all.

AMMONIA.—In all natural waters a certain amount of ammonia is found, and in almost all polluted waters the amount is sufficient to enable it to be estimated. In rain-water the ammonia is derived from the traces existing in the atmosphere; in upland waters

it is due also to the decay of vegetation or to the manuring of cultivated ground, or to the presence of animals. Ammonia exists in water in two conditions which are known as "free" (or saline) and "albuminoid" ammonia respectively. These are both estimated, the estimations being performed on the same quantity of water. The process followed is that of Wanklyn: A retort or flask of 1 litre capacity is connected to a condenser and water is distilled in the apparatus until the distillate is free from ammonia. Then into the cleaned flask are placed 500 c.c. of the sample, a few pieces of ignited pumice to prevent "bumping," and about one-third gramme of ignited sodium carbonate. The apparatus being connected, the distillation is started and four separate lots of distillate, each of 50 c.c., are collected in Nessler cylinders. To each of these cylinders is added 2 c.c. of Nessler solution, when, after standing for a few minutes, those containing ammonia show a yellow colour the depth of which depends on the amount present. The amount of ammonia present in each Nessler cylinder is found by running known amounts of ammonium chloride solution (each c.c. = 0·01 milligramme ammonia) into other cylinders, filling to the 50 c.c. mark with ammonia-free water, adding 2 c.c. of Nessler, and, after waiting till the colour has properly developed, comparing the colours with those obtained as distillates. When correct matches have thus been made the total of c.c. of ammonium chloride solution used multiplied by 0·01 will give the amount of free ammonia-in milligrammes in 500 c.c. of sample. This, when divided by 500 and multiplied by 70, will give the amount in grains per gallon. To the 300 c.c. of water left in the distillate flask 40 c.c. of alkaline permanganate solution is added, and the distillation continued; four further amounts of 50 c.c. each are collected which, when Nesslerised and the tints compared with standard ammonium chloride solution as above described, will give the amount of albuminoid ammonia. Should the last cylinder collected show signs of ammonia, a quantity of ammonia-free water should be added to the distillation flask, and the distillation continued until all the albuminoid ammonia has come over. In the case of a water containing a very excessive quantity of ammonia, the colour obtained on Nesslerisation is too dense to allow of accurate comparison. Such a water must be suitably diluted with ammonia-free water and the distillation repeated. It is not possible to lay down any rules as to the amounts of saline and albuminoid ammonia which should not be exceeded in potable waters, beyond stating that most pure waters contain but little of either, so that if any appreciable quantity is found, more especially if the amounts present exceed what has previously been found in the same water, the cause should be sought for. Saline ammonia is sometimes found in perfectly pure chalk waters; albuminoid ammonia is found in peaty waters (owing to vegetation). Where there are a number of wells sunk in similar strata, if the results are compared, it will be found that any which are characterised by higher figures for ammonia than the rest will be found to show other abnormal figures, and an examination of the surroundings of the well will in most cases give a clue to the cause of the pollution. Various causes may give rise to the presence of ammonia other than pollution. A water containing nitrates (as many pure waters do) may, on passing through a galvanised pipe, have some portion of the nitrates reduced to ammonia. Ammonia has also been found in waters owing to leakages of liquor from gas works; in this case it is probable that traces of sulphocyanides would also be detected.

Oxidised Nitrogen.—This exists almost always in the form of nitrates (of calcium or sodium), but nitrites are also, though very rarely, found. Nitrates are characteristic of chalk waters, but are generally found in varying amounts in most waters. Upland waters, peaty waters, pure lake waters, rain-water, and pure river waters contain very little, while polluted river waters and polluted wells may contain large amounts. Here again no hard and fast rule can be laid down, and the analyst

must to a considerable extent be guided by comparisons. If a shallow well-water, concerning the surroundings of which no information can be obtained, and nothing is known as to the nature of the soil, contains more than ·5 of a grain per gallon it would be regarded as suspicious, and if the chlorine figure were also high (*i.e.*, above 3 grains to the gallon, reckoned as chlorine) these figures would lead to suspicion. If the figure for saline ammonia is very low, it would show that a considerable amount of oxidation had taken place, which is more or less correctly termed "past pollution," while if it is also high, present or recent pollution is suggested. Nitrates when once formed are not very liable to further alteration, except that they may be withdrawn by the various organisms that are natural to some waters, or, in the case of surface waters, they may be assimilated by growing plants. They therefore form a more or less permanent record of pollution in those cases where they cannot be produced by the geological conditions. There are three or four methods in use for the estimation of nitrates, the two most generally employed are as follows:—(1) The reduction of the nitrates by the copper-couple method, or by aluminium foil and soda. The copper-couple is prepared as follows: take a piece of thin zinc sheet about 2 in. by 4 in., clean it with hydrochloric acid and immerse it for 3 minutes in a 3 % solution of copper sulphate. Copper will be deposited on the zinc as a blackish coating. Wash the coated zinc with distilled water, place it in a wide-mouthed bottle holding about 200 c.c., and rinse it with the water to be tested and then fill up with the water and leave in the dark for 24 hours. At the end of this time the nitrates (and nitrites, if present) will be all converted into ammonia. When the reaction is complete, take out 10 c.c. by a pippette and, after diluting with ammonia-free water, distil as in the estimation of saline ammonia, Nesslerising as previously described. (2) The other method in common use is the phenyl-sulphate method, which, though possibly not quite so accurate, has the merit of quickness. Evaporate 70 c.c. of the sample to be tested in a porcelain dish, finishing the evaporation over a water-bath. At the same time evaporate 5 c.c. of a standard solution of potassium nitrate, made by dissolving ·722 of a gramme of potassium nitrate in a litre of distilled water. Each c.c. of this standard solution will be equivalent to ·0001 gramme of nitrogen. When the two evaporations above-mentioned are complete, 2 c.c. of phenyl-sulphate is added to the dried residue in each dish. It must be stirred so as to mix with every part of the dried residue and the dishes should be warmed (but not heated beyond a steam heat) for 3 minutes. The phenyl-sulphate is made by mixing 18·5 c.c. of strong sulphuric acid, 1·5 c.c. of water, and 3 grammes of phenol. When the mixture of phenyl-sulphate and residue has been well mixed and warmed it is diluted with 10 or 20 c.c. of distilled water, poured into a Nessler cylinder, made distinctly alkaline with ammonia, and diluted to exactly 100 c.c. in each case. It will be found that the standard, as soon as it has been made distinctly alkaline, assumes a clear yellow colour. The sample, if nitrates are present, will also show a yellowish tint which corresponds to the amount of nitrates present. If the liquid is clear, nothing more is required except to make a quantitative comparison of the tint with that of the standard. If on the other hand it is cloudy, it needs filtering. The comparison is made as follows:—Place the two cylinders side by side on a sheet of white paper by the window, hold one vertically in each hand, and look down through the liquids at the paper. If the two tints are the same colour, the sample contains a precisely equal amount of nitrates to the standard, and as 70 c.c. were taken, the amount would in this case be ·0005 gramme of nitrogen per 70 c.c., or ·5 grains per gallon. If on the other hand the tints are not equal, pour out from the deeper of the two into a graduated (100 c.c.) cylinder, until the liquid left in the Nessler glass matches the other. Then reckon how many c.c. are required to do

this, by subtracting the number of c.c. poured out from 100. For instance if the sample was the deeper and the tints matched after pouring out 20 c.c., the 80 c.c. left, being equal in tint to the standard, the sample must contain more nitrogen than the standard, the calculation being:

$$\text{Sample} = \frac{100}{80} \times {\cdot}5 = {\cdot}62 \text{ grains}$$

per gallon of nitrogen. It sometimes (though very rarely) happens that an impure water will produce instead of a pure yellow tint, a greenish or brownish-yellow; in such a case this process cannot be relied on, as unless the tints are similar in character it is impossible to compare them with accuracy.

Nitrites.—As mentioned above, nitrites are very seldom found in potable waters, but as their presence is universally regarded as a suspicious sign, it is customary to test for them. The two tests usually employed are the iodide test and Gries's test. The iodide test is performed as follows:—To 20 c.c. of the sample, add a few drops of pure sulphuric acid, a crystal of potassium iodide free from iodine, and a few drops of chloroform. Shake up, and then allow the chloroform globules to coalesce, when they will have a pink tint if nitrites are present. A "blank" using distilled water must be made and should show no pink colour whatever. The Gries's test is performed by adding a few drops of sulphuric acid to 20 c.c. of the water and then a little solution of metaphenylene-diamine hydrochloride. If nitrites are present an orange-yellow tint will appear. This may be compared against a standard made from nitrite of silver. Standard solutions cannot be accurately prepared from sodium or potassium nitrites, on account of the instability of these salts.

Poisonous Metals.—The chief poisonous metal to be sought for in water is lead, though it is customary also to test for copper and iron and sometimes zinc. Lead is sometimes found in water owing to the action of soft water or water containing vegetable acid on lead pipes. It is a disputed point as to what quantity of lead in a water should cause its absolute condemnation, but all authorities are agreed that even very small quantities are highly objectionable. As lead is a cumulative poison there should not be more than one-fiftieth of a grain per gallon in drinking water, and it is believed that even this small quantity may have prejudicial results. To test a drinking water for lead 100 c.c. may be placed in a Nessler cylinder, 1 drop of acetic acid added, and then a few drops of a clear, freshly made solution of sulphuretted hydrogen. On standing for a few minutes, if lead is present, a darkening corresponding in intensity to the amount of lead present will be seen on holding the cylinder above a sheet of white paper. A similar tint is then prepared by taking various exact amounts of a dilute standard solution of acetate of lead and treating them in the same way, until a tint is obtained which matches the sample. As copper might be present (though it is rarely found) it is necessary to carry out a confirmatory test for lead which may be done by placing 100 c.c. of water in a Nessler glass and adding two or three crystals of potassium bichromate, together with a drop of nitric acid. After stirring up and allowing to stand for 5 minutes a yellowish turbidity will make its appearance. This turbidity can be compared more or less quantitatively, but if a large quantity of the sample water is available, say several litres, it may be evaporated to a small bulk and the precipitated bichromate of lead filtered off and weighed.

Phosphates.—Many waters may be tested for phosphates with advantage. If they are present in marked quantity they must be regarded as evidence of pollution, more particularly if they occur in conjunction with high nitrates and high chlorides. On the other hand their absence cannot be regarded as any proof of purity, as in a water containing much calcium carbonate phosphates might be precipitated and filtered out by the strata from which the water is being derived. In unpolluted water probably only traces of phosphates will be found, but in polluted

waters a sufficient quantity is often obtainable from 2 litres to admit of weighing the precipitate. Evaporate 2 litres to 10 c.c. Add a few drops of nitric acid until faintly acid, warm to 80° C., and add 2 or 3 c.c. of ammonium molybdate solution, warm and stir for 5 minutes. The precipitate (if phosphates are present) is of a canary yellow colour. It may be filtered off and weighed. The weight multiplied by ·0374 gives the amount of P_2O_5 present in the quantity operated on.

Organic Matter in Water.—In addition to the various suspended solids in water mentioned under the microscopic examination of water, there is always a certain amount of organic matter in solution. This is usually low in pure water, and high in polluted waters. The organic carbon and nitrogen were formerly ascertained by Frankland's combustion process. This is but seldom performed nowadays, as the estimation of the free and albuminoid ammonias allow an arrival at the same conclusion in a more expeditious fashion. Organic matter (whether nitrogenous or otherwise) is determined by one or other of the "Moist Combustion" processes. The method in general use in this country consists in treating the water to be tested with an acid solution of potassium permanganate. The organic matter in solution which is present in a suitable state absorbs oxygen from the permanganate, and the excess of permanganate not used in oxidation is estimated by titration at the end of a stated time. The process, originally due to Forchammer, has been modified in various ways, so that figures by different observers should not be expected to compare, unless they employ the same details of procedure. Different workers also perform their moist combustion tests at different temperatures, causing a divergence of results. The consequence is that the figure is often of no significance to any one besides the analyst. In some waters much of the organic matter present is in an insoluble condition, and therefore has but little action on the permanganate. The following method is one that is frequently employed:—Place 250 c.c. of the sample of water in an absolutely clean 500 c.c. flask and a similar quantity of distilled water free from oxidisable matter in another flask. Warm both flasks on a water-bath to 80° F., add to both 10 c.c. of standard permanganate solution (each c.c. of which contains 0·1 milligramme of available oxygen), and 10 c.c. of 25 °/₀ sulphuric acid. Keep the flasks warmed to 80° F. If the colour becomes sensibly paler in the sample, add 10 c.c. more of the permanganate solution to both flasks. At the end of 15 minutes (or 4 hours) cool both flasks, and add to each one or two crystals of potassium iodide. The pink colour will turn to a yellow, due to the liberation of iodine by the reaction of the permanganate with the iodide. The liberated iodine dissolves in the excess of potassium iodide. The contents of each flask are then titrated with a standard solution of sodium hyposulphite, finishing the titration in presence of a few drops of starch solution. The standard solution of permanganate employed contains ·395 grammes of potassium permanganate in a litre of water; the 'hyposulphite' solution should contain about 1 gramme to the litre; and the special sulphuric acid is made by adding 1 volume of acid to 3 of water and then adding small quantities of permanganate solution until a very faint pink colour remains. Specimen calculations of this method and the others mentioned in these articles will be found in "The Chemical and Biological Examination of Water" (Pearmain & Moor).

Interpretation of the Results Yielded by Analysis. — The general conclusions to be drawn from the various methods that are employed in water analysis have been dealt with under each individual process. It remains only to add that it is impossible to generalise to the extent of laying down hard and fast figures for the purpose of designating "pure or impure" waters. All the different features must be considered, and while it is often possible to class one water as pure and another as certainly polluted, there remain a considerable proportion which must be regarded as falling into an intermediate class, namely,

doubtful, or only to be used with caution. In some cases a doubtful water is the only available one, and as it is quite useless to prescribe boiling because it will not be effectively or continuously carried out, the only alternative is to provide efficient filter beds for large supplies, and an efficient filter as well in the consumers' houses (*see* "DOMESTIC FILTERS").

C. G. M.

Water, Bacteriology of.—Origin of Bacteria in Water and Influences Affecting them—Bacterial Indicators of Pollution—Enumeration of Bacteria—Detection and Estimation of B. Coli Communis—The Streptococci—B. Welchii—The Typhoid Bacillus—The Comma Bacillus—The Preparation of Media.—The nature and number of bacteria in water vary enormously. From a sanitary standpoint the actual number of organisms is secondary in importance to their origin. While some bacteria may be regarded as natural to water, others are washed in from the soil, and in a sewage polluted water organisms of excretal origin will be found. Provided the soil be unpolluted the bacteria derived from it do not affect the purity of a water. Should, however, the soil be contaminated with excrement, the purification of water percolating through it is materially dependent on two factors. The bacteria natural to soil have a strong antagonism for foreign bacteria, with the result that organisms of fæcal origin more or less rapidly disappear, which disappearance is hastened by the temperature and medium not being conducive to their multiplication. In the absence of fissures the soil has a pronounced filtering property which precludes the passage of bacteria through more than a certain thickness. The depth necessary to prevent pollution varies with the nature of the soil, the amount of polluted matter, the rate of flow of water, and the existence of defects allowing freer passage of water. The variation in the number of organisms present in a water is governed by conditions which operate by either increasing or decreasing them. During a shower the rain-drops carry down the aërial bacteria; as the shower continues the content of bacteria in the rain diminishes. This number of organisms is generally small, and pollution from this source can be regarded as immaterial. After a heavy rain, however, the bacteria in bodies of water may be decreased owing to dilution, or increased through the washing in of soil organisms. The lowering of the plane of saturation by excessive pumping from a well, through draining a larger area, may bring a polluted soil within the drainage area. An open well will *cæteris paribus* contain more organisms than a closed one (Savage). When flowing at a slow rate, or when stationary, the mineral and vegetable particles to which some of the organisms adhere subside, and the bacteria may also congregate together to form zooglœa, in which case they will settle more rapidly than when isolated. This "sedimentation" constitutes the most important factor in the self-purification of water. In the clarification of water with alum, &c., and in softening by the addition of lime water, as in Clark's process, bacteria are mechanically carried down.

BACTERIAL INDICATORS OF POLLUTION.—The pollution of water with sewage naturally increases the content of bacteria, and a large number of organisms would appear suspicious. This presumption is strengthened if a large proportion of the bacteria will grow at blood heat, and if the count on gelatine (grown at 18° to 22° C.) contains an excessive proportion of organisms liquefying gelatine. Some of the bacteria found in pure waters, however, liquefy gelatine, others grow at blood heat, while the mere enumeration of organisms often does not give positive evidence of the purity. It is, therefore, necessary to search for certain bacteria which are normal to fæces, and which, for a time at any rate, are capable of leading a saprophytic existence in water. Should these be found in appreciable numbers a conclusion is generally justified that the water is unfit for use. The organisms generally sought for are the *Bacillus coli communis*, *streptococci* and *Bacillus Welchii* (*Bacillus enteritidis sporogenes*). These exist in large numbers in human fæces,

but they, or organisms possessing very similar characters which do not admit of ready differentiation, are also found in the excreta of animals and birds, and thus do not necessarily indicate alvine pollution of human origin. Pollution with animal matter of any kind, however, seriously discounts the suitability of a water for drinking purposes.

Bacteriological Examination of Water.—A committee of the Royal Institute of Public Health formulated a scheme for the bacteriological examination of water to which English workers generally adhere. The committee give as the minimal number of procedures: (*a*) Enumeration of the bacteria present on a medium incubated at room temperature (18° to 22° C.); (*b*) Search for *Bacillus coli* and identification and enumeration of the organism if present. In addition the majority of the committee recommend: (*c*) Enumeration of the bacteria present on a medium incubated at blood heat (36° to 38° C.); (*d*) Search for and enumeration of *streptococci.* As a routine procedure the search for *B. Welchii* is considered unnecessary. Unless the necessary inoculations into media can be made within 3 hours of collection, the sample must be packed in ice, but even then the examination should be commenced as soon as possible, as even ice packing does not prevent an alteration in the bacterial character of a water. The recommendations of the Royal Institute of Public Health committee are mainly followed in the following analytical scheme, and the composition of the media used are given at the end.

Enumeration.—For organisms developing at room temperature nutrient gelatine or distilled water gelatine may be used. With a polluted water the former allows more organisms to grow than the latter, while with a pure water a larger count is generally obtained with distilled water gelatine. The use of both media, therefore, affords useful information; but when only one gelatine is used the "nutrient" form should be employed. With a pure water the number of organisms developing on gelatine is generally more than ten times the number of those growing on agar at blood heat. In the case of a polluted water this ratio of organisms developing on gelatine to those developing on agar may become 10 : 2, or even less. With a polluted water the colonies liquefying gelatine may increase to more than one-tenth the total number on gelatine. For the counts on gelatine three tubes of nutrient gelatine are melted in a water bath at 40° C. Then three sterile Petri dishes are inoculated respectively with 0·5 c.c., 0·3 c.c., and 0·2 c.c. of the sample run in from a sterile graduated pipette. The tubes of gelatine are taken from the water bath one by one, the plugs removed, the mouths singed in a Bunsen flame, and poured one into each dish. By tilting the Petri dishes several times the water is mixed with the liquefied gelatine. The Petri dishes are placed on a flat surface to solidify, and then incubated at from 18° to 22° C. The number of organisms on the gelatine plates is counted with the naked eye at the end of 72 hours, any doubtful colony being determined with the aid of a lens. It is, however, necessary to inspect the plates daily, as sometimes the number of liquefying colonies renders an earlier count necessary. The counting is best done against a black background, and when the colonies on a plate are very numerous a Pakes's disc may be used to lessen the labour of counting. The total number on the three plates will give the number in 1 c.c. For the enumeration of organisms growing at blood heat, two tubes of agar are melted in a water bath at 100° C., cooled to 40° or 45° C., and the contents run, with the usual precautions, into separate sterile Petri dishes containing 1·0 and 0·1 c.c. of the sample. Expedition is necessary, or the preparation will go "lumpy." The plates are put in the blood-heat incubator and counted at the end of 40 to 48 hours. For contaminated waters it may be necessary to dilute the water ten or one-hundredfold in order to render the individual colonies sufficiently discrete to be counted. All the foregoing experiments should be done in duplicate.

The organisms developing aërobically on gelatine at room temperature may be as few as five or ten per c.c. in a water from a deep well or spring, and do not usually exceed 100 to 150 in a good water. A count of 500 per c.c. is sometimes obtained in surface waters free from pollution, but anything over this should raise suspicions. A thousand organisms per c.c. will generally condemn a sample.

Detection and Estimation of Bacillus Coli Communis.—Two single-strength tubes of MacConkey's medium, preferably made with lactose instead of glucose, are inoculated with 0·1 c.c. and 1·0 c.c. of the water. One double-strength tube is inoculated with 10 c.c. of the water, and two (in the case of a deep well water, five) other double-strength tubes with quantities of 20 c.c. each. (The tubes for the reception of the quantities of 20 c.c.'s should contain 20 c.c. of the double strength medium, so that it is not diluted with more than its own bulk of water.) The tubes are incubated at 37° C. (or better at 42° C.) for 2 days. The reddening of the medium showing the production of acid and the collection of gas in the inner tube afford presumptive evidence of *B. coli*. Other organisms, chiefly of alvine origin, however, ferment MacConkey's medium with the production of acid and gas, and it is, therefore, necessary to isolate and identify the colon bacillus. For this purpose the tube containing the smallest quantity of the sample which shows the reaction is used to inoculate solid media for the isolation of individual organisms. To effect this isolation two good loopfuls of the reddened MacConkey medium are inoculated into a suitable quantity of sterile water for dilution, and some of this is smeared over the surface of several sloped gelatine tubes. Or the suspected medium may be smeared over plates of Conradi-Drigalski agar. After pouring the Conradi-Drigalsk agari into the sterile Petri dishes, these should be placed in the blood-heat incubator, with the lids tilted to allow escape of moisture, for 2 hours. This partial drying is necessary to prevent colonies running together. (These can be incubated at blood heat, and thus save time.) Any colon bacilli will appear as large red colonies. Several suspicious colonies are inoculated into separate broth tubes, incubated for 12 to 24 hours at blood heat, and then examined in the fresh condition to ascertain motility, while a cover-glass preparation of the broth is made and stained by Gram's method.[1] *B. coli* is Gram-negative, and feebly motile. Occasionally the motility is not apparent. Its presence is, however, a guide as to the best tube to select for further work. Subsequent procedure depends on what attributes are regarded as typical of the colon bacillus. Houston considers that the term should only be applied to "flaginac" organisms, *i.e.*, those producing fluorescence in neutral red glucose-peptone water, acid and gas in MacConkey's glucose medium, indole in peptone water, and acid and curd in milk. The Royal Institute of Public Health committee give the following as characteristic of typical *B. coli:* A small, motile, non-sporing bacillus, growing at 37° C., as well as at room temperature, which is decolourised by Gram's method, does not liquefy gelatine, and in a gelatine stab grows well to the bottom of the stab (facultative anaërobe). It produces permanent acidity in milk, curdling the same within 7 days at blood heat, ferments glucose and lactose with production of both acid and gas. It is also desirable to show the production of indole, the change

[1] Gram's Method.—Some of the culture is smeared over a cover-glass, dried, fixed, and stained with anilin gentian violet solution (saturated alcoholic solution of gentian violet, 30 c.c.; anilin water, 100 c.c.) for 5 minutes; then immersed in iodine solution (iodine, 1 part; potassium iodide, 2 parts; distilled water, 300 parts) for one half to 2 minutes, when the film should have the colour of a used tea-leaf. The cover-glass is removed from the iodine solution, drained, and immersed in methylated spirit until the gentian violet colour no longer comes away from the preparation. The preparation may be washed and counter-stained with eosin, or after washing it may be dried, mounted, and examined straight away. (n.b.—Anilin gentian violet solution does not keep for long.)

in Grübler's neutral red, and the yellowish brown growth on potato. Both Savage and Hewlett agree in the main with these characters. Therefore the pure culture in a broth tube which is Gram-negative and feebly motile should be inoculated into the following media: (*a*) gelatine, both in stab and surface cultures; this can conveniently be done in the same tube. A pearly white growth appears along the streak, which does not liquefy the gelatine. This tube should be observed for 10 days to exclude a liquefying organism. If a gelatine shake culture be also made, bubbles of gas will be produced in the medium. Gas bubbles may also be observed along the stab in the stab culture. (*b*) Litmus milk incubated at blood heat will be reddened and curdled. (*c*) Neutral red glucose peptone water—a yellow colour with green fluorescence—is produced. (*d*) Peptone water. Indole is produced in 2 days.[1] (*e*) Various sugar media, especially lactose and glucose media, both of which are fermented with production of acid and gas.

Organisms differing from the typical colon bacillus in one or more respects are frequently met with, which are known as "atypical." The precise significance to be attached to them is uncertain; but at the same time the probability that they were originally derived from excreta must not be overlooked. Savage is of opinion that "the nearer these glucose fermenting coli-like bacilli approach typical *B. coli* in their characters, the more nearly are our numerical standards for that organism applicable to them, while if they lack essential characters a proportionately greater number must be present to justify an adverse opinion."

Should typical *B. coli* be isolated in this way, it was obviously present in the amount of water inoculated into the original MacConkey tube from which the subcultures were made, and is duly reported as present in this quantity. This particular datum is by far the most important of the whole of the ordinary examination; but, like the other data, requires a very wide and comprehensive experience for its correct interpretation. Several "working standards" have been proposed for *B. coli*. Savage considers that its presence in 100 c.c., or less, of deep well or spring water, or in 10 c.c., or less, of shallow well water justifies an attitude of great suspicion. Pakes suggests the condemnation of water containing the organism in 20 c.c., or less. In upland surface waters the significance of the colon bacillus is less certain owing to the probability of its derivation from the excreta of grazing animals, and Savage is of opinion that its presence in even 2 or 1 c.c. "means contamination, but not necessarily a contamination which it is essential to prevent."

Streptococci.—Proof of the presence of these organisms affords a valuable confirmation of other results pointing to pollution, but less significance can be attached to their absence. The medium used in the preliminary detection of coli (MacConkey's lactose bile-salt medium) favours the growth of streptococci, and they should be looked for in hanging drops. Our knowledge of the subject does not at present allow any decided opinion on the significance of different species of streptococci, and they are only looked for as a class. It is uncertain whether they are capable of a saprophytic existence for longer or shorter periods than *B. coli*. Savage, after referring to the inapplicability of arbitrary standards to streptococci, suggests that similar standards to those he has advocated for *B. coli* may be provisionally used.

Bacillus Welchii (this name is applied by Chester to the organism or class of organisms

[1] The Indole Reaction is obtained by adding to 10 c.c. of the peptone water culture of the organism 1 c.c. of a 0·1 % solution of sodium nitrite, and then allowing a few drops of concentrated sulphuric acid to trickle slowly down the side of the test tube. It is placed in the incubator for half an hour to render the pink or deep red colour more plain. A blank should be performed and the suitability of the peptone for the purpose proved. (N.B.—The cholera spirillum produces a nitrite in the culture medium and gives the reaction on the addition of acid alone.)

originally described by Welch and Nuttall, which Hewlett believes to be identical with the *B. enteritidis sporogenes* of Klein).—This organism is regarded as of less importance as an index of pollution than formerly, though Thresh attaches considerable importance to it. It has to be sought for in large quantities of water, the usual method being to pass 500 c.c. of the sample through a Pasteur-Chamberland candle, suspend the deposit in 5 c.c. of sterile water, and inoculate three milk tubes with 3 c.c., 1 c.c., and 1 c.c. of this concentrated water respectively. Hewlett's method of conducting the test, though cumbersome, is much more satisfactory: Ten large boiling tubes, each containing 50 c.c. of sterile milk, are inoculated with equal amounts of the water; melted vaseline is poured on the surface of the milk to exclude the air, and the tubes heated to 80° C. for 15 minutes. After 2 days' incubation at blood heat, *B. Welchii* produces a clear whey and a honeycombed mass of casein, while the gas produced is shown by a bubble under the vaseline plug. The *B. butyricus*, which is regarded by some as a non-pathogenic form of *B. Welchii*, gives a similar reaction, and the only satisfactory means of differentiation is to inject 2 c.c. of the whey subcutaneously into a guinea-pig of about 200 grammes weight, when *B. Welchii* will kill the animal in 48 hours.

THE DETECTION OF THE TYPHOID BACILLUS.—This organism is seldom looked for except when an epidemic is in progress. Allowing 10 or 12 days as the incubation period, and a few subsequent days for the probability of an epidemic to be appreciated, a sufficient time may have elapsed before the water is suspected to allow the organism time to die out. This, coupled with the difficulty of its detection in water, accounts for the extreme rarity with which it is found in water. A large number of methods for the detection have been proposed, to which want of space prevents reference. One which is regarded as the most satisfactory, and has been used with success by the author, is given: *H. S. Willson's Method.*—Sufficiency of a 10 °/₀ solution of alum is added to the water to give 0·5 gramme of alum to the litre. A precipitate of aluminium hydrate is formed which entangles the bacillus. The vessel is shaken, and the water centrifugalised. The deposit is rubbed up with a little of the water, and plated out on Conradi-Drigalski, or malachite green agar. On Conradi-Drigalski agar the typhoid bacillus comes up in small, clear, blue, dewdrop-like colonies. All suspicious colonies should be worked out. The typhoid bacillus is actively motile, does not stain by Gram, ferments glucose producing little acid but no gas, has little or no effect on lactose or saccharose, produces a little acid in litmus milk but no coagulation; except in rare instances it produces no indole; on potato it gives a moist, shining, grey growth that is almost invisible, except when the potato has an alkaline reaction, when the growth may be yellowish. The flagella should be stained, and the agglutination with typhoid serum ascertained. Although neither *B. alkaligenes* nor *B. sulcatus* (the two organisms most likely to be mistaken for the typhoid bacillus) agglutinate with typhoid serum, some varieties of the colon bacillus do.

THE ISOLATION OF THE CHOLERA SPIRILLUM.—This organism is with difficulty detected in water. Moor and Hewlett ("Applied Bacteriology") recommend the addition to several hundred c.c. of the water of 1 °/₀ peptone and 1 °/₀ salt, making faintly alkaline with sodium carbonate, placing in Erlenmeyer flasks, having a layer not more than an inch deep in each flask, and after loosely capping the flasks with filter paper, incubating at 37° C. Hanging drop preparations are made at intervals of 10, 15, and 20 hours respectively from the top of the liquid, and examined for the organism. Agar plates are prepared and incubated at blood heat, and any suspicious colonies are subcultured and examined for indole production, &c. A peritoneal inoculation into a guinea-pig is recommended.

It should be pointed out that a bacteriological examination of water should never be

attempted without a good previous knowledge of the principles of bacteriological technique, and an appreciation of the very many ways in which errors may arise. In inexperienced hands the experiments may be absolutely misleading.

Preparation of Media.—The broth, gelatine, and agar media are made to a reaction of + 10 (Eyre's scale). That is to say, after the media have been prepared they are made neutral to phenolphthalëin, and then to every litre 10 c.c. of normal acid are added. This "standardisation" is a matter of importance, particularly in the enumeration of organisms, as different counts result from using media of different reactions. As the reaction changes on keeping, the media should be used within a month of preparation.

Distilled Water Gelatine.—Ten per cent. gelatine in distilled water.

Nutrient Gelatine.—Nutrient broth containing 10 °/₀ gelatine. (In hot weather 15 or 20 °/₀ gelatine is necessary.) After the gelatine has dissolved, the white of an egg is added, the vessel placed in the steriliser for an hour before filtration, filtered, standardised, run into sterile test tubes (10 c.c. into each), the tubes plugged with sterile wool, and steamed for 20 minutes on three successive days.

Nutrient Broth.—An infusion of 1 lb. of gravy beef free from fat in a litre of tap water is known as *acid beef broth.* When rendered alkaline and salt peptone added nutrient broth is obtained. For most purposes Lemco can be substituted for beef. This allows a broth of a more constant composition, although many workers prefer the use of beef broth for the preparation of nutrient gelatine. A useful broth may be made from 10 to 20 grammes of Lemco, 10 to 20 grammes of Witte's peptone, 5 to 10 grammes of salt, and a litre of water. To this gelatine or agar may be added, or it may be standardised to + 10 reaction and used as broth.

Nutrient Agar.—This is prepared in the same way as nutrient gelatine, 1½ °/₀ agar being substituted for gelatine.

Bile-Salt Broth (MacConkey & Hill's Medium).—Sodium taurocholate 0·5 gramme, peptone 2 grammes, and glucose (or lactose) 0·5 gramme, are dissolved in 100 c.c. of water, filtered, and neutral litmus solution added to give a distinct blue colour. This strength is known as "single strength," and is used for amounts of 1 c.c. and under of water. Some media of "double strength" is also prepared and measured in amounts of 10 c.c. and 20 c.c. into Durham's tubes for the reception of similar amounts of water. (Durham's tubes are test tubes, of various sizes, containing small inverted tubes which become filled with liquid during sterilisation, and when an organism ferments a constituent of the media with production of gas; this gas is observed in the inner tube.)

Conradi-Drigalski Agar.—This medium is very tedious to prepare, and is best purchased.

Peptone Water.—1 °/₀ Witte's peptone and ½ °/₀ common salt in water. After heating to dissolve the peptone, it is made faintly alkaline. From 1 to 2 °/₀ of glucose, lactose, mannite, saccharose, dulcite, or other carbohydrates may be added, the medium tinged with litmus and used for the differentiation of the varieties of *B. coli*, *B. typhosus*, &c.

Milk.—Separated milk just neutralised with sodium carbonate and sterilised for an hour on three successive days. This may be tinged with litmus. (Litmus milk.)

Neutral Red Broth.—One-half per cent. solution of Grübler's neutral red in water is added in the proportion of 1 c.c. to every 10 c.c. of a glucose broth containing ½ °/₀ glucose.

W. P.

Water, Sampling of.—When taking a sample of a house supply the tap should be allowed to run for 5 or 10 minutes first, but when an examination for lead is to be done the first runnings from the tap in the morning must be tested. When a public supply is to be examined the sample should be collected from a hydrant in direct connection with a main. A sample from a river, lake, or reservoir should be taken some distance from

the banks, care being taken to exclude any floating scum and avoiding the stirring up of mud. The quantity required for the chemical analysis is half a gallon. The sample should be taken in a Winchester quart bottle, which should have a glass stopper, and should be first washed with strong sulphuric acid and then rinsed with distilled water until free from acidity. The bottle should be rinsed two or three times with the sample before filling. No sealing-wax, linseed paste, or other form of sealing material should be used, but the stopper should be tied down with a piece of parchment paper or clean rag. The bottle should be packed in straw or other suitable material and sent off to the analyst with the least possible delay. Particulars of the date of collection, the source of the sample, and the proximity of sources of possible pollution should be given. In the case of a well the depth and particulars of the strata should be given. When a bacteriological examination is needed a special sample must be taken. The bacteriologist who is to perform the analysis will always prefer to send a bottle, as he can then be certain of its sterility. The bottle should contain at least 200 c.c., and should be sterilised by heat. When taken from a tap the water should be allowed to run for 10 minutes first, and when taken from a tank or other body of water the stopper should be removed about a foot below the surface. The sample of a supply should be taken direct from the main, as in passing through a cistern an increase of the number of bacteria may occur. If possible the sample should reach the bacteriologist within 3 hours of collection, and should be packed in ice and sawdust if further delay is unavoidable. This cooling of the sample will to a certain extent inhibit the multiplication of bacteria, but even when so packed it is necessary to limit the interim between collection and examination as much as possible. When *B. Welchii* is to be sought for an extra litre of the sample should also be taken, and when suspected of conveying typhoid a Winchester quart sample should be supplied. Every precaution should be taken to preclude the entrance of extraneous organisms during the collection, and the hands should not come in contact with the portion of the stopper going in the bottle or with the mouth of the bottle.

W. P.

Water-Carriage System.—The water-carriage system is the method of removing solid excreta by means of a flow of water, as opposed to its collection in a dry state in pans or privies (*see* "CONSERVANCY SYSTEMS") or with water in cesspools. It involves the use of water-closets, flushed sometimes by means of the household slops, but in the vast majority of cases by an independent supply of water, and of a system of underground pipes. The latter, when serving single houses, are known as "drains," and when serving a number of houses as "sewers." These convey also the household slops and water soiled by use in factories, &c., and generally the whole or a part of the rain-water. (*See also* "WATER-CLOSETS," "DRAINS," "SEWERS," "THE COMBINED SYSTEM," "THE SEPARATE SYSTEM.")

A. J. M.

Water-Closets.—The conditions required in these fittings are cleanliness and safety. The appliances must therefore be so constructed and designed as to expose no surfaces liable to be soiled without the certainty of

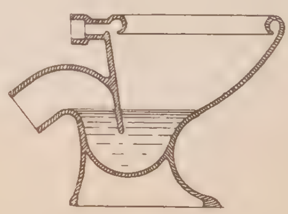


FIG. 1.—Wash-down Closet.

them being cleaned. They must also retain a sufficient volume of water and expose an adequate area thereof to insure the immediate and complete immersion of fæcal matter, in order that this may be prevented from staining the basin and from giving off bad odours. At the same time the water retained in the basin must not be too great in quantity to be

entirely changed by an ordinary flush of water from the cistern connected to the closet. The efficiency of the closet trap must further be considered as forming a component part of the desirability of the closet as a whole. The only sanitary forms of closets at present available are :—

1. Wash-down } Pedestal closets ;
2. Siphonic }
3. Corbel closets ; and
4. Valve closets.

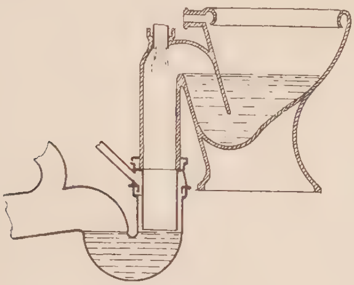


FIG. 2.—Siphonic Pedestal Closet.

These are all made in a variety of forms but differ only in detail. For typical specimens, see Figs. 1 to 4. The wash-down, closet is the best form of closet apparatus to be had for general purposes. It is equally suitable for the tenement of the poor and the mansion of the rich. It may be made use of for either a ladies' or a gentlemen's closet, and when in a suitable position may also be utilised as a "slop-hopper," as well as for the purpose for which it is primarily intended. In selecting a closet of this type, the chief points to be attended to are, as already stated, the area, depth, and position of the water retained in the basin and the depth of the "seal" of the closet trap. The flushing rim should be such that, in flushing, every portion of the interior of the basin is washed, and that the water forms a jet or cascade directed towards the outlet. This latter is necessary to force fæcal matter out of the basin. The inside surfaces of the basin should, of course, be perfectly smooth, and as white and free from ornament as possible. The various designs of flowers, &c., with which the interior of closets are frequently decorated only tend to conceal dirt. Similarly, in order to avoid accumulations of dust and other impurities, the outer surfaces of these and all other forms of closets should be free from all raised ornamentation, and preferably also perfectly white. Lastly—and this is of great importance—the outlet arm of the closet trap should be so formed and placed that, whatever may be its connection with the drain or soil pipe, the joint will be in view and easily accessible. This is necessary both in order that the joint may be made in the first place, and that, subsequently, any damage which might occur to the joint will be readily noticed. The Corbel closet is identical with the wash-down, with the exception that it projects from the wall into which it is built instead of standing on the floor. Siphonic closets are also very similar in appearance and general design to wash-down. The material difference is that their contents are siphoned out of the basins instead of being flushed out when the water in the cistern is discharged. This is brought about by discharging a portion of the flushing water on the outlet side of the trap of the basin, a vacuum being thereby created. When of good type, siphonic closets are very desirable fittings, as they make a full use of the available flushing water and are practically noiseless.

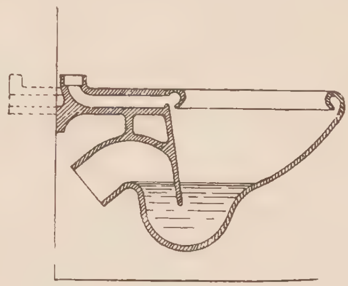


FIG. 3.—Corbel Closet.

In valve closets the water is retained in the basin by means of a valve or flap at its outlet. The following points should be attended to in choosing them :—

1. The overflow arm should be open at the top, to permit of cleansing by hand.

2. The overflow arm should be trapped and arranged to receive a small quantity of water whenever the basin is flushed.

3. The valve should be so placed that, when opened, it will cover the outlet of the overflow arm where the latter joins the valve box, in order to preclude the possibility of paper, &c., finding its way into the overflow pipe and thus choke it.

4. A ventilation pipe (usually known as a "puff" pipe) should be provided on the valve box.

5. The valve box should be porcelain enamelled in its interior.

6. The working parts of the valve should be as simple and as strong as possible, and such as to insure its proper closing at all times.

7. The flushing-rim should be continuous all round the basin, which should never be flushed by means of a "fanspreader."

8. The water-supply valve (and service pipe thereto) should never be less than $1\frac{1}{4}$ in. in diameter. Where the available head of water is less than 10 ft., it should be $1\frac{1}{2}$ in. in diameter.

9. A drawn lead siphon trap should be provided immediately under the valve box,

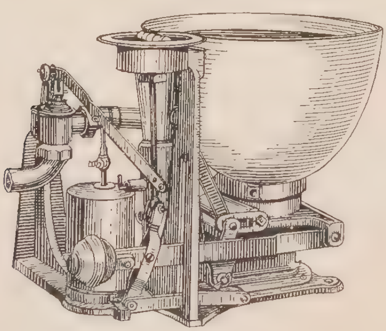


Fig. 4.—Valve Closet.

in order to disconnect the closet from the soil pipe. The valve alone is insufficient for this purpose, although it offers additional security.

G. J. G. J.

Water-Hammer.—The concussion caused in water mains and fittings when running water is suddenly stopped by the closing of a valve or cock. This concussion may work loose holdfasts and cause water pipes to burst or split. That the water pressure is greatly increased under these circumstances is shown by the following figures published by Sir Alexander Binnie, as a result of experiments carried out by him:—

	Pressure in lbs. per sq. in.	
	Tap.	Main.
Before opening tap.. ..	125	125
When open	20	120
When shut quickly.. ..	550	220

Water Meters.—Domestic supplies of water are usually charged for in England on the basis of a certain percentage on the annual rateable value of the premises, ranging from about 5 °/₀ on the larger properties to 7 °/₀ on those of small rentals, but no fixed rule obtains. Large trade, garden, and other supplies are mostly measured by meter, and charged for according to the quantity used. Water meters may be classified under three heads, viz.: positive or piston meters, inferential or turbine meters, and volume or capacity meters.

In the positive meter the actual quantity of water supplied is measured by admitting it into a cylinder of known capacity, at the top and bottom, alternately, of a piston, thus causing it to move up and down in the cylinder, the strokes made by the piston being recorded upon a dial face by means of suitable wheel-work.

Inferential meters contain a small turbine which is worked by the current of water passing through the meter; the registration is based upon the assumption that the rate of rotation of the turbine is proportionate to the velocity of influx of the current of water, and the revolutions are recorded by suitable mechanism as before.

Volume or capacity meters are largely used in the United States of America, and to a

limited extent in this country. Broadly speaking, they consist of a casing of gun-metal or vulcanite in which works a vulcanite block, serving both as piston and valve. An objection frequently raised to this class of meter is that they seldom possess any provision for taking up wear, and that, though intended to measure the volume passing through them they do not measure small flows. For large flows they are said to be very accurate, and possess the merits of simplicity, smallness, and cheapness. For the "Bee" meter, which is of the disc type, it is also claimed that small particles of foreign matter may pass through the meter without wedging the measuring chamber. This meter will also run with a very small "head."

Of the different classes of meters, those of the "positive" class are the most accurate, and correctly record very small flows of water. They are, however, large in size, expensive, and occasionally stop owing to incrustation or gritty matter passing in the water, thus cutting off the supply much to the annoyance of the consumer. On the other hand, should an inferential meter stop registering the water passing through, it does not stop the supply, a fact which, though satisfactory from the consumer's point of view, is obviously the reverse for the water authority.

Inferential meters may sometimes not revolve under a small flow turned on very slowly, but are sufficiently accurate for registering ordinary supplies when subject to regular inspection. They are also cheap and of small size, and are suitable for measuring large trade supplies taken at a fairly uniform rate; but the positive meter is best adapted for correctly recording small consumptions. (*See also* "Venturi Meter" and "Water Supply, Prevention of Waste" (Deacon's meter).)

W. H. M.

Water Power.—The power of a waterfall is governed by two things: the quantity, and therefore the weight, of water flowing in a given time, and the "head" or vertical height through which it descends. The theoretical horse-power will be equal to

$$\frac{62{\cdot}4\,Q\,H}{33{,}000}.$$

Q = Quantity of water in cubic feet per minute.

H = Head of water from tail race in feet.

The available power will depend upon the efficiency of the motor and the conditions under which it is installed (*see* "Turbines" and "Water-Wheels," *also* "Head Pressure, loss of"). Q may be ascertained by measurement over a weir or estimated from the sectional area and velocity of the stream (*see* "Gauging of Streams.") H should be taken concurrently (*see* "Hydrostatic Head").

E. L. B.

Water-Seal. (*See* "Trap.")

Watershed or Catchment Area.—A tract of country the rainfall upon which gravitates naturally to one common water-course or outlet. Every river or stream has its own contributory watershed from which the supply of water is derived. (*See* "Water-Supply.")

Water Supply, Domestic.—The principal points requiring attention in domestic water supplies are those relating to storage, quantity, distribution, and filtration. Roughly, the amount of water necessary for various domestic requirements is as follows:—

For each person, per diem	25 gallons.
,, ,, horse	15 ,,
,, ,, pony, donkey, or mule	6 ,,
,, ,, head of cattle	8 ,,
,, ,, sheep or pig	1 ,,
,, ,, 2-wheel carriage	8 ,,
,, ,, 4-wheel ,,	15 ,,
,, ,, square yard of garden	$0\frac{1}{4}$,,

For fire-extinguishing purposes, 200 gallons per minute for 30 minutes. According to Dr. Parkes, the amount of water used per head in a family of fairly cleanly people is as follows:—

Cooking	0·75 gallons.
Fluid as drink (water, tea, coffee, &c.)	0·33 ,,
Ablution, including a daily sponge bath, taking $2\frac{1}{2}$ to 3 gallons	5·0 ,,
Share of utensil and house washing	3·0 ,,
Share of clothes (laundry) washing	3·0 ,,
Total, say .	12 gallons.

With fixed baths and water-closets this is insufficient, and 25 gallons must be allowed as a minimum.

The materials of the piping used for the conveyance of water through the house must be chosen with due regard to its nature, more especially when the water is such as will act upon lead. Lead is the chief mineral impurity to be guarded against in a domestic water supply, and certainly the most dangerous. It has a cumulative poisonous action, and when taken continuously, even in minute quantities, accumulates in the system and remains in the body until serious illness, and frequently fatal consequences, ensue. Amongst others of the troubles which may be ascribed to lead poisoning are: anæmia, constipation, "plumbism" or lead colic, and local paralysis. The capacity of waters for dissolving lead and their rapidity of action varies considerably. As a rule the softer and purer the water the greater the danger of that kind. Cases have occurred in which the action has been so great and rapid that standing all night in the lead service pipes has been sufficient to determine the presence of lead in poisonous quantities in the water in the morning. On the other hand, certain soft waters which might be expected to dissolve lead have little or no action upon that metal. Other waters, owing doubtless to seasonable variations, are operative upon lead at one time although inoperative at others. The action of water upon lead is of two kinds: the one leading to a solution of the lead, the other to its erosion and deposit in a loose powdery form, which is readily swept away by the flow of water and conveyed to the consumer. When water is known or suspected to have a plumbo-solvent action, wrought iron, tin-lined or block-tin piping should be employed for its conveyance. Wrought-iron pipes have the disadvantage, however, that they rapidly corrode in the interior if of small bore, and that they also suffer considerably from outward corrosion. The water flowing through them is also apt to become discoloured by rust, which, though perhaps harmless in itself and only temporary in many cases, is nevertheless noticeable and objectionable to taste and sight. If iron pipes are used they should be lined with a continuous tube of tin. Tin-lined tees, bends, connectors, and other fittings are available, and should be used in connection with them. Galvanised wrought-iron piping is unsuitable for the conveyance of potable water, as almost all waters—both soft and hard—have a solvent action upon the zinc coating of the pipes; and all zinc salts are poisonous. Zinc poisoning, although occasionally fatal, is not, however, as serious as lead poisoning, nor are its effects cumulative. Block-tin pipes, although in most respects the most satisfactory, are, perhaps, too costly for use in all cases. A cheaper piping is lead-incased tin piping, which consists of an internal pipe of tin, varying from one-thirty-second to one-sixteenth of an inch in thickness, covered by an outer pipe of lead. Such pipes are made in all the usual sizes and strengths. Great care is necessary in their selection, as seams or blisters on the inner surfaces of the pipes and other faults in the tin lining occur. The continuity of the tin lining must be preserved, so that no lead is brought in contact with the water. Great care is necessary in making joints on this kind of piping, as the tin melts inside the pipe unless the joints are made with great dexterity. Nor is there any method of preventing a shrinkage of the tin on applying the heat necessary for making a joint on the lead pipe, even if the molten tin is prevented from blocking the pipe. So liable are joints on lead-incased tin

pipes to prove unsatisfactory, that it is well to join the pipes in all cases by means of the special connectors made for the purpose. These are made on the principle of a cap and lining connection, and join the pipes without the use of solder or heat.

When water is not lead-solvent, lead piping may be safely made use of, and will prove the most convenient to handle and fix, as it may be taken in all directions without the use of special bends. The water companies' regulations as to strength must, however be complied with. As will be seen from the following table, the requirements vary greatly in different districts:—

Weights of Service Pipes, in Lbs. per Lineal Yard, Required by Various Water Companies:—

Name of Water Company.	Diameter of Pipe in Inches.					
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{4}$
London	5	6	$7\frac{1}{2}$	9	12	16
Manchester Corporation	—	6	—	9	12	16
Glasgow (Loch Katrine)	—	7	—	10	14	18
Sheffield..	5	7	9	11	16	$22\frac{1}{2}$
Norwich..	5	7	9	11	16	$22\frac{1}{2}$
Nottingham	—	7	—	11	16	22
Market Harborough ..	5	6	$7\frac{1}{2}$	11	16	20
Kent	—	5	7	9	12	—
West Surrey	4	$5\frac{1}{2}$	—	9	14	20
Caterham	5	6	8	10	14	—
Colne Valley	5	7	9	11	16	—
Sevenoaks and Tonbridge	—	5	7	9	12	15

Water pipes, whatever the material of which they are made, should be carefully fixed to avoid air-locking, which is especially frequent in the case of lead pipes that have not been sufficiently supported and which have in consequence sagged. The pipes should all be fixed with a fall, so that the entire system may be emptied through taps, should that be necessary. The pipes should also invariably be fixed on inner walls to protect them from frost, and where this is impossible special provision should be made to prevent freezing (*see* "Frost"). A stop-cock should be provided at the point where the main enters the house, and other stop-cocks so placed that each section of the water supply system may be shut off for repairs if necessary without entirely cutting off the water supply of the house. While soft water may be dangerous, excessively hard water frequently proves a nuisance, by reason that it produces soap curds, and causes deposits and incrustations in boilers and hot water pipes.

Soap curds form a greasy, slimy deposit in sinks and other sanitary fittings, and in waste pipes and drains, and these partly block the pipes and frequently become highly offensive, besides forming one of the minor difficulties of sewage disposal.

Incrustations in boilers, hot water pipes and kettles increase the consumption of fuel and tend to block the pipes, which may sooner or later have to be taken out and cleaned or renewed. They are also liable to become a source of danger by causing boiler explosions, either through the blockage of the circulation pipes or by the cracking of the crust within the boiler, which would permit cold water to come into sudden contact with the highly heated iron of the boiler. In certain cases it is, therefore, desirable to partly soften the water before use by removing the temporary hardness. This, indeed, is the only portion of the hardness which can be conveniently removed, as permanent hardness can only be eliminated by the introduction of substances which would render the water unfit for dietetic purposes. Temporary hardness may be removed by Dr. Clark's well-known process, which consists of the addition of 1 oz. of quicklime for each degree of hardness to every 700 gallons of water. This lime, by combining with the bicarbonate held in solution in the water, reduces the latter to the form of a carbonate, which, being insoluble in water, is precipitated. Continuously working apparatus for the purpose are made by various makers, and answer the purpose well if attended to periodically.

Impurities in suspension, if they exist in water in a building, can do so only as the result of shortcomings on the part of the authority supplying the water or of the householder. The impurities are various, and may

range from particles of dust to small fish. Nevertheless, even where, as doubtless in most cases, the filtration of the public water supply is carefully attended to, it must be remembered that there are times at which filtration is not perfect. Such, for instance, would be the case during severe frosts and during the first day or two on which a filter bed is used. Nor are filters always effective in removing bacteria. All natural water contains them, in common with air, food, and even our tissues, and the vast majority of them are harmless or even beneficial. The danger lies in the few bacteria which are branded as "disease germs," which (though as a rule absent) may at any moment be found in drinking water. To remove these and any suspended impurities which might be present in domestic drinking water, it is a wise precaution to resort to household filtration in almost all cases, provided, of course, such a process is properly carried out and regularly attended to.

Whilst it is desirable that water should be rendered clear and sparkling, the most important functions to be expected from a domestic filter are:—

1. That it should prevent the passage of pathogenic or disease-producing bacteria; and
2. That it must add no fresh impurity or bacteria to the filtrate.

In these two all-important requirements many of the filters now upon the market utterly fail. Their filtering mediums, so far from being capable of arresting bacteria, rather favour their propagation and multiplication by providing a suitable nidus for their development. Water passed through such a filter, if this has not been frequently cleaned and sterilised, is apt to be far more dangerous than unfiltered water. In order to gain some knowledge as to the relative efficiency of filters, Drs. Sims Woodhead and Cartwright Wood some years ago carried out a series of valuable experiments by subjecting all known filters to stringent tests by passing pathogenic organisms through them. As a result of these experiments, which confirmed previous investigations by continental authorities, the investigators gave it as their opinion that the only forms of filters which did not admit the passage of disease germs were the candle filters known as the "Pasteur-Chamberland," the "Berkefeld," the "Aëri-Filtre Mallié," the "Pukall" filter, Slack & Brownlow's, and Duff's Patent Germ-Proof filters. All these filters are fixed to the mains and the water drawn through them. They need only be made use of for drinking water.

For information on the sources and construction of works of water supply *see* "Water Supply." G. J. G. J.

Water Supply (General).—Rainfall — Evaporation and Percolation—Classification of Sources of Supply—Springs and Deep Well Water—Upland Surface Waters—Surface Water from Cultivated Land—River Water—Quantity of Water per Head of Population—Character of Water and Causes of Impurity—Physical Characteristics—Action of Water on Lead—Construction of Waterworks—Catchment Areas and Storage—Compensation Water—Gravitation Supplies—Waste Weir, &c.—Outlets and Valve Towers—Siphon Outlets—Creeping Flange—Aqueducts—Service Reservoirs—Distribution of Water—Intermittent and Constant Supplies——Prevention of Waste—Fire — Pipes — Dual Supplies—Water Main Scraping.

Water Supply (General).—According to the census of 1901 the population of England and Wales was about 32½ millions of people. This involves a water consumption of, approximately, 1,000 million gallons per day, calculating upon the basis of 30 gallons per head per day. At 6*d*. per 1,000 gallons, this volume of water represents an annual value of over £9,000,000. It will be seen, therefore, that the collection, treatment, and distribution of so large a quantity of water is, necessarily, a work of very considerable importance, especially having regard to the fact that the business of obtaining reliable sources of supply to meet the continual growth of population is a matter of ever-increasing difficulty, particularly in droughty periods,

such as were experienced during the years 1900 to 1902.

Rainfall: Sources of Water Supply.—All supplies of fresh water come primarily from rainfall, although collected under varying circumstances from river, lake, underground basins, or other sources. Water is obtained in its purest form by distillation. The heat of the sun is continually drawing up large quantities of moisture from the surface of both land and sea, thus forming clouds, which, in due course, return their water to the earth in a purified form. The water supply of any district therefore depends primarily upon the rainfall of the locality, and the extent and character of the gathering ground or "catchment area." The average rainfall of the whole of England and Wales is about 33 to 34 in. per annum, but varies considerably according to local circumstances. The fall in any given district depends largely upon its geographical position, the direction of the prevailing winds, and the distribution of hills, mountain ranges, forests, &c. That in the western and southern parts of this country is considerably in excess of the fall in the eastern counties. The rainfall on the western coast varies from 40 to 70 in. per annum, and as an exceptional instance, 190·28 in. were registered at Stye, in Cumberland, in 1883. On the eastern coast from 20 to 30 in. may be taken as the average, but in the year 1901, which, for England and Wales, showed an average deficiency of more than 13 °/₀ there were several places recorded in the county of Essex with rainfalls of between 14 and 15 in. only. The year 1901 was followed by an even drier year which resulted in a cumulative deficiency[1] for the two years in England and Wales of 31 %, and over the British Isles as a whole there was a deficiency of rainfall in these two years equal to a quarter of one year's fall. In many parts this caused something approaching a water famine, and gave great anxiety to those responsible for the management of water supplies. This dry period was followed by one of exceptional humidity—the percentage of excess of rainfall in 1903 (above the average 1870—1899) being approximately 28 % in England, and 33 % in Wales. For water supply purposes it is the minimum rainfall upon which all calculations must be based, and the late Mr. G. J. Symons, F.R.S., has given the following limits of fluctuation, based upon the results of a large number of observations extending over many years, which are believed to be within 7 % of the actual fall, viz.:—

The wettest year will be 45 % more than the average.

The driest year 33 % less than the average.

The driest two consecutive years 26 % less than the average.

And the driest three consecutive years 21 % less than the average. In providing "storage" for water supply purposes it is found to be useless to attempt to equalise supply over a longer period than three consecutive dry years, as by so doing there would be many years when the storage reservoirs would not get filled. It would be no use, for example, to provide sufficient storage to prevent overflow during the year of greatest rainfall, or even the mean of a 10, 15, or 20-year period, because the daily addition this would make to the yield during dry years would not be commensurate with the cost of the additional storage capacity. The water which falls in the form of rain is ultimately disposed of in several ways. That which runs off the surface, generally spoken of as "surface water," eventually joins the neighbouring streams and rivers, unless intercepted and impounded in some storage reservoir, as, for example, at Vyrnwy, in North Wales, by the Corporation of Liverpool, and at the Elan Valley (Mid-Wales) by the Corporation of Birmingham. It frequently happens that surface water flowing from a watershed or catchment area consisting largely of cultivated lands, and containing a considerable population, becomes seriously polluted, as is the case with waters of this class coming from the watershed of the river Thames.

[1] Below the 30-years' average, 1870—99, which for England and Wales, was 34·28 in.

Evaporation and Percolation.—Another part of the rainfall is lost by evaporation, or is absorbed by trees and plants to form part of their tissues; and a third part percolates into the earth and ultimately joins the store of underground water recoverable for use by pumping, or part of which may reappear in the form of "springs," possibly at very distant points. The relative amounts of water disappearing in the above ways vary according to the nature of the soil, the contour of the land, and the season of the year. Rain falling upon a highly porous material, like gravel, sand or chalk, will rapidly disappear by sinking into the ground; but, if the district be largely composed of hard rock or stiff clay very little will percolate into the subsoil. The district around Brighton, consisting as it does of chalk, is almost wholly devoid of streams or surface water of any kind, the whole percolating into the porous chalk and thus feeding the underground sources from which the town derives its entire supply. Of the total rainfall during any year, the most important is that falling during the winter half; it is this which replenishes the sources of water supply depleted during the summer. That falling during the warm season has but comparatively little effect owing to the large amount drawn off by evaporation. Summer rain, however, reduces the demand upon the waterworks as, of course, the daily consumption by the town is less during showery or dull weather. It is clear, therefore, that the period of the year in which the rain falls is of more importance than the total fall of the year, and a shortage is more likely to result from a dry winter than from a dry summer. In managing storage water it is very desirable not to draw upon it, if possible, until late in the summer season, as any deficiency in the supply is generally felt towards the close of the year. Evaporation is hastened by the rain falling in numerous separate showers, and upon an impermeable soil; forests and vegetation afford considerable shelter to the ground and largely protect it from the influence of evaporation. In this connection it may be noted that the Departmental Committee appointed in 1902 by the President of the Board of Agriculture recommended in their report "that the attention of corporations and municipalities be drawn to the desirability of planting with trees the catchment areas of their water supply." The percolation of rainfall into the surface of the ground depends largely upon the geological and physical conditions which obtain. It depends upon the amount of rainfall, the porosity of the surface strata, and the slope and extent of the permeable surface. It varies inversely as the evaporation is greatest in the winter season or during long and heavy rains, and least in warm and showery weather. The question of the degree of percolation has a direct bearing upon that of the level of water in wells and borings, and of ground-water in general—the annual rise and fall of which is frequently termed "seasonal variation."

Classification of Sources of Supply.—The different sources from which supplies may be obtained have been classified by the Rivers Pollution Commissioners in their sixth report in the following manner:—

Wholesome	1. Spring water	Very palatable.
	2. Deep well water ..	
	3. Upland surface water	Moderately palatable.
Suspicious	4. Stored rain water ..	
	5. Surface water from cultivated land ..	Palatable.
Dangerous	6. River water to which sewage gains access	
	7. Shallow well water ..	

Springs and Deep Well Waters, where available in sufficient quantity, as a rule afford excellent supplies, but in some cases yield water of exceptional hardness, or occasionally it may be highly impregnated with salt, iron, or other constituents which render it unfit for domestic and trade purposes. (*See articles* "Springs," "Wells," and "Underground Water.")

Upland Surface Waters.—These waters are collected from the high rocky mountainous districts of Wales and the north of England, and Scotland, which afford excellent sources

for the water supply of large towns where the appropriate works for their collection, storage, and in some cases filtration, have been carried out. They must be clearly distinguished from the waters flowing from low-level catchment areas, consisting of cultivated lands with farmsteads, villages, and the usual rural population, such as in the valley of the Thames, where much of the water reaching the river becomes more or less polluted almost at its very source. For the supply of many large towns in this country, upland surface water flowing from watersheds consisting of the older geological formations such as granite, the Silurian and Devonian strata, mountain limestone, &c., is impounded by means of large earthen or masonry dams built across the valleys of the upper reaches of mountain streams. Birmingham has carried out a large scheme of this description at Elan Valley (Mid-Wales) to supply that city with 75,000,000 gallons of water per day. This is conveyed to the inhabitants by an aqueduct 73 miles in length. Similar water undertakings have been carried out by the Liverpool Corporation at Vyrnwy in North Wales, by Bradford in the Upper Nidd Valley (Yorkshire), by Manchester at Lake Thirlmere (Cumberland), by Glasgow at Loch Katrine (Perthshire), and many other towns in the north. A large gravitation scheme for the utilisation of the waters of the Upper Wye and Usk (Mid-Wales) has also been seriously proposed for the better supply of London.

Upland surface waters of this character are usually almost free from animal impurities, are peculiarly soft, but sometimes contain much vegetable or peaty matter. In a series of some 200 analyses by the Rivers Commission, the amount of dissolved solids in upland surface water from the igneous rocks was ascertained to vary from about $1\frac{1}{2}$ to 3 parts per 100,000, about 15 parts from sandstones and shales, and as high as 77·5 parts in water from the chalk and limestone watersheds. There was an almost entire absence of nitrates and chlorides, and a small amount only of organic nitrogen, showing the organic matter present to be of vegetable origin and to be derived from uncultivated lands.

The larger authorities deriving supplies from upland catchment areas usually seek either to purchase the watersheds or to obtain certain rights and means of control of the contributory areas, in order that the necessary precautions may be observed and a systematic inspection instituted, to safeguard the water supply from possible pollution.

Rain Water.—In rural districts, where better means of supply are unattainable, the collection and storage of rain water falling on the roofs of buildings forms a valuable source of supply. Some of the disadvantages in connection with its utilisation, however, are the many precautions necessary to prevent its pollution, the uncertainty of the rainfall, the length of the dry season from year to year, and the large size of the reservoirs necessary to equalise yield and supply.

Rain water is very soft and well aërated, and when not contaminated during its precipitation, or by imperfect methods of collection and storage, is the purest of all natural waters. In the immediate neighbourhood of towns, however, it receives many impurities from the atmosphere, including organic matters, germs, sulphurous and sulphuric acids, which give it an acid reaction, and large quantities of tarry and carbonaceous matter derived from the combustion of coal. In an examination of London rain water, Angus Smith found 2 parts per 100,000 of sulphuric acid; 4 to 5 parts in Manchester rain water; and in Glasgow water 8 parts. It therefore happens that when such water falls on the roofs of buildings it dissolves lime, iron, lead, zinc, &c., from the lead and zinc flats, walls, gutters and pipes, and also contains much soot and foreign matters settled upon the roof, and may thus become very hard and impure. Where rain water is used for domestic purposes, the roofs, gutters, &c., should be kept quite clean and free from dust, soot, bird droppings, cats, leaves, and other polluting factors. If it is desired to use the whole available rainfall the roofs should be

high-pitched and covered with an impervious material, such as good Bangor slates, so that there may be a minimum of loss from evaporation and absorption. The quantity of water to be obtained from any given roof or other catchment area for rain water will depend principally upon the average rainfall of the district and the area of the roofing. There will, of course, be small losses from evaporation and other causes to be deducted from the total. Where rainfall statistics are not obtainable the figure must be obtained by means of a rain-gauge in a similar manner to that followed in ascertaining the fall on a large catchment area for a gravitation scheme of supply. In this connection the "Rules for Rainfall Observers," issued by the "British Rainfall Organisation," founded by the late G. J. Symons, F.R.S. should be followed. For use in ordinary localities the "Snowdon rain-gauge" is recommended. It is 3 in. in diameter and easily fixed by four stakes driven into the ground. The glass measuring jar when filled to the top division holds half an inch, and each division on the scale marked thereon denotes one-hundredth of an inch of rain. The rain is conducted by a funnel to a bottle within the gauge, and the previous day's fall should be measured each morning in the graduated glass and duly recorded.

To find the quantity of water falling upon any roof area, the following formula may be applied :—

$$\frac{A \times R}{277{\cdot}274} = \left\{\begin{array}{l}\text{Number of gallons received}\\ \text{by the roof in a year.}\end{array}\right.$$

Where A = the area of roof in square inches; and R = average annual rainfall in inches; and 277·274 = cubic inches in 1 gallon of water.

Or for practical purposes, the calculation may be made by multiplying the roof area in square feet by the annual rainfall in inches and then by ·52. This is practically equal to multiplying the roof area by half the rainfall, and in this simplified form the rule is within 4 % of the true quantity. In calculating roof area the horizontal area must be used, not the area as taken on the slope. In England the average amount of roof area per person has been put at 60 sq. ft., and if we take 30 in. as the average annual rainfall, this gives a yield per person of 935 gallons, or 2·5 gallons per day, that is assuming there is no loss from evaporation. It may also be useful to note that 1 in. of rain gives 4·673 gallons per square yard of surface, or 22,617 gallons (equal to 101 tons) of water to the acre. In estimating the annual yield of water from rainfall the average fall of the three driest years is a safe basis to calculate upon. As a useful practical rule for ascertaining the requisite amount of storage for a rain-water tank, it may be noted that the minimum tank capacity to be provided should be at least capable of holding one-fourth the annual rainfall. Rain water may be stored in brick or slate storage tanks, built either above or below ground. Fig. 1 shows details of a suitable tank, built underground, in either brick or concrete, the inside being rendered in cement. The incoming rain water passes through a fine copper wire screen fixed at A to intercept leaves and other *débris*, through a sand or polarite filter at B, before passing into the storage tank, and the suction of the pump is protected with a fine copper gauze shield at C.

Surface Water from Cultivated Land.—This as a source of supply can only at best be looked upon with suspicion, being open at all times to dangerous pollution. It should not be used except under extreme necessity. The impurities consist largely of organic pollution from the manuring of lands, animals, and human wastes. Any such waters employed for domestic use would require thorough subsidence in storage reservoirs and efficient filtration under watchful management before being delivered for public supply. There are many towns, however, that still take their supplies from rivers and streams which consist very largely of water of this class, whilst many others, owing to the growth of population and increasing pollution of the water-courses, have had to abandon their river supplies altogether or extract the water at a

point nearer the source of the stream before pollution has taken place. The river Tame was originally the main supply to Birmingham, but in 1869 it had become so polluted that it was abandoned for domestic use, and many other similar instances may be cited.

River Water.—Much that has been said of "surface water from cultivated land" applies equally to river waters. On the use of river water subjected to human and other forms of pollution there is, however, considerable diversity of opinion as to how far it is safe for large populations to depend thereon for domestic purposes; but with respect to these sources of supply, it may be said that the bulk of medical and scientific opinion agrees

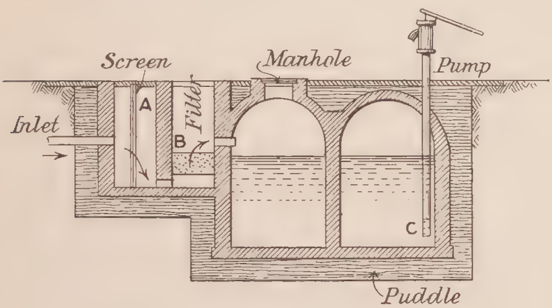


Fig. 1.—Rain-water Storage Tank.

that the drinking water of a large town ought not to be obtained from rivers and streams passing through cultivated and inhabited lands. Works that deal with this class of water have usually been long established, and, since their construction, the water-courses drawn upon have as a rule gradually become more and more polluted, until ultimately their abandonment will doubtless become a necessity. The possible means of pollution of a stream flowing through cultivated lands are so very numerous that the river usually becomes in effect the common sink for the drainage and wastes of the watershed through which it flows. The Rivers Pollution Prevention Acts and the work of River Conservancy Boards have minimised the evil, but much remains to be done.

The opinion of the Royal Commissioners on Water Supply (1892) in regard to the use of the Thames, which receives a considerable amount of pollution and is subject to frequent and heavy floods, is of interest in this connection. The Commissioners reported:—"We are strongly of opinion that the water, as supplied to the consumer in London, is of a very high standard of excellence and of purity, and that it is suitable in quality for all household purposes. We are well aware that a certain prejudice exists against the use of drinking water derived from the Thames and Lea because these rivers are liable to pollution, however perfect the subsequent purification, either by natural or artificial means, may be; but having regard to the experience of London during the last 30 years and to the evidence given to us on the subject, we do not believe that any danger exists of the spread of disease by the use of this water, provided that there is adequate storage, and that the water is efficiently filtered before delivery to the consumers." In the same year (1892), however, occurred the very severe epidemic of cholera in Hamburg, which admits of no doubt as to the agency of water in propagating disease. The cities of Hamburg and Altona both take their water supplies from the River Elbe—Altona from a point some 7 miles below the discharge of the sewage of both cities, and Hamburg from about 7 miles above. In the latter instance the water taken was simply passed through ponds or settling tanks, but, owing to the increase in the demand for water it was pumped through too rapidly to permit of much improvement by subsidence.

At Altona, a little lower down the river but continuous with Hamburg, the water was filtered through sand. The condition of the raw water was even worse than that at Hamburg, yet in Altona only 328 persons died, against 8,605 in Hamburg. The boundary line between the water areas of Hamburg and Altona was clearly marked out in places by the cases of cholera; in some streets, for example, with one side supplied by Hamburg and the other side by Altona, the cholera stopped at the dividing line. A scheme of

filter beds was rapidly pushed forward by Hamburg and brought into use the following year, when the city had equal immunity from the disease except for a short period when there was a sudden but limited rush of cases which were found to be due to a defect in the masonry which allowed unfiltered Elbe water to pass into the supply. The beneficial effects of the new Hamburg filters and of those at Altona which protected that city from a cholera epidemic in 1892 are thus demonstrated in a most practical and instructive manner, which applies also to the 6 millions of people in "Water London."

Amongst other large centres of population depending upon river supplies may be mentioned Berlin, New York, Chicago, Boston, and Philadelphia.

The natural organic purification of rivers during their flow is a subject which has received much attention, but is one upon which great difference of opinion exists. It was contended by the late Dr. Tidy that water containing 20 °/₀ sewage would, in the course of a 10 or 12 miles flow, become purified by natural oxidation, whilst, on the other hand, Dr. E. Frankland, by experiments on the rivers Irwell and Thames, arrived at the opinion that a 200 miles flow would be insufficient for the purpose. After exhaustive inquiries the Royal Commission on River Pollution of 1868 arrived at the conclusion that "there is no river in the United Kingdom long enough to effect the destruction by oxidation of sewage put into it at its source." The principal enactments, other than local special Acts, dealing with the pollution of streams and watercourses are: The Public Health Act, 1875; the Rivers Pollution Prevention Acts, 1876 and 1893; the Waterworks Clauses Act, 1847; the Public Health Acts Amendment Act, 1890; the Local Government Act, 1888; and the Public Health (London) Act, 1891.

Quantity of Water Required per Head of Population.—The quantity of water that must be provided per head of the population is a fluctuating amount depending largely upon local habits and conditions. It will vary (1) according to the nature of the locality, whether residential or manufacturing in character; (2) the method of drainage of the town, whether upon the "water-carriage" system or "conservative" system; (3) the amount required for trade purposes, garden purposes, carriage-washing, &c.; (4) for municipal purposes, such as sewer flushing, street watering, public conveniences, washing streets and pavements, &c.; (5) the percentage of waste from mains and fittings.

The total quantity of water supplied for all purposes will vary from about 20 gallons per head per day in residential towns up to 30 or 35 gallons per head in manufacturing towns, and in exceptional cases even the latter figure may be exceeded. The actual quantity supplied day by day will also vary according to the season of the year, whether summer or winter, whether wet or dry. The consumption is usually greater during frosty weather, owing to waste from burst pipes and mains, also to householders allowing their taps to "run" during the night with the view of preventing the water freezing in the pipes. The actual flow through the town mains will also vary considerably during different hours of the day. The maximum draught on the distribution mains may occur at any time between the hours of 8 a.m. and 5 p.m., and is frequently at its highest between the hours of 9 a.m. and noon. The mains must, of course, be capable of passing water at the maximum rate without undue loss of "head" or pressure. As an approximation, the maximum rate of draught may be taken at twice the average consumption in the 24 hours. In regard to the rate of flow in the water mains, a well-established empirical rule fixing the velocity at 3 ft. per second has been laid down as suitable for fairly large mains.

Character of Water from Different Sources and Causes of Impurity.—Water, though pure at its source, may receive impurities in a variety of ways before it reaches the consumer. As met with in nature it owes its characteristics largely to the geological

strata or other physical conditions with which it has come into contact. Water derived from the older formations, as igneous rocks, granite, or millstone grit, is usually very pure, contains only a small quantity of minerals in solution, and a very insignificant amount of organic matter. Waters from limestone and dolomite are clear and bright in appearance, but contain sulphates of calcium and magnesium in large quantities, and consequently have a high degree of permanent hardness. These waters are not good for manufacturing purposes and should not be used for domestic supply if a softer water can be obtained.

A considerable number of towns in the Midlands and North of England are supplied from wells sunk in the New Red Sandstone formation, which yields a large quantity of water, usually of a good class well suited for public supplies. The towns of Birkenhead, Nottingham, Wolverhampton, St. Helens, and many others draw supplies from this strata. Birmingham and Liverpool have also in the past taken large quantities from the same source. The water at Nottingham and Wolverhampton is between 8° and 10° of hardness, whilst at St. Helens it is 23° before the softening treatment and 10° after. Bristol is supplied from springs in the limestone conglomerate, and deep wells in the new red sandstone, and the water has a hardness of about 18°.

The chalk is one of the most important of water-bearing strata and yields water of excellent and wholesome quality. It is always sparkling and agreeable to the palate on account of the large quantity of carbonic acid in solution; it contains calcic carbonate, often in large quantities, and is therefore hard, but softens considerably upon boiling. A large number of towns in the south and east of England are supplied from this source, as well as a considerable part of London. The hardness may amount to 16° or 18°, whilst that from the lower greensand, below the chalk, is frequently much less, the "Mid-Kent" supply from this source being about 10°.

Traces of iron are to be found in practically all waters, and it is often met with in natural spring or deep well waters to an extent sufficient to render the water unfit for use and of a very disagreeable taste. This is frequently the case with water derived from sandstones, such, for example, as the Ashdown sands, or any strata largely impregnated with iron. The small quantity of one-fifth of a grain per gallon of water will impart an unpleasant chalybeate taste to the water. Iron is removable by precipitation with lime and oxidation. It may frequently be removed from deep well waters by thorough aëration, time being allowed for precipitation. It is, however, much more expeditiously and conveniently removed by a system of forced aëration under pressure in mechanical filters, the suspended oxide being afterwards filtered out (*see* "MECHANICAL FILTRATION").

Surface and subsoil waters present many variations in composition according to the nature of the ground where they are collected. The surface water from the millstone grit, Silurian and Devonian formations, from heaths, moorlands, and uncultivated lands, is usually pure, but if the catchment area contains much peat it will be of a brownish colour and occasionally acid in reaction. From cultivated and manured lands considerable quantities of organic matter may be found in solution, and even in the absence of organic matter nitrates, nitrites, chlorides, and phosphates are sure to be present, indicating some previous contamination with animal matter.

The water from graveyards and marshes must always be regarded as dangerous supplies; they contain organic matter in suspension or solution in addition to nitrates and nitrites. Rain water, although a useful source in rural districts if properly collected, cannot be utilised in towns owing to the many impurities taken up from the atmosphere and the roofs of houses.

Other means of contamination of water supplies may occur from the washing of large quantities of *débris* and decaying vegetable

matter into open water conduits. If the water is collected from land dotted over with dwellings, farmsteads, agricultural buildings, &c., sewage may find its way into the water conduit, springs, or wells, and if such sewage contamination carry the specific poison of any disease, such as typhoid or cholera, it may thus speedily contaminate large quantities of water, including the rivers or streams into which it ultimately flows.

Trade refuse, such as the effluents from a dye works, gas, brick, or chemical works, would seriously pollute a water supply if allowed to percolate into a porous strata and thus reach the well, conduit, or stream from or

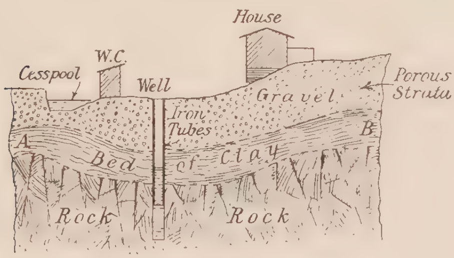


Fig. 2.

by which water is derived or conveyed. In rural districts the fouling of water chiefly arises from the proximity of dwellings, cesspools, stables, or pig-styes to the well or other source of supply. Fig. 2 illustrates how impurities may readily reach a well sunk in a porous strata. If in such a case there had been an impermeable bed of clay (*A B*) overlying the rock, and the well properly lined with iron tubes or brickwork from the ground surface to the rock in such a way as to completely exclude the top waters, a good and pure supply might have been obtainable from the rock below if of a porous and permeable nature.

Physical Characteristics of Good Drinking Water.—It will be convenient here to briefly summarise a few of the leading physical characteristics of a good drinking water. It must be clear and entirely free from sediment or suspended matter. Ordinary printed matter should be clearly read through at least 18 in. depth of water. It should be colourless or bluish if looked at through a depth of 2 or 3 ft., and should be bright and sparkling showing that it is well charged with air and carbonic acid. The water should have the pleasant sparkling taste of good water, and be free from brackish or other unpleasant or peculiar taste. There must be no smell other than the peculiar indescribable smell which fresh spring-water yields. It should be soft to the touch and dissolve soap easily.

Hardness of water is that property which causes it to decompose a certain quantity of soap before a lather can be formed. It is usually expressed in degrees upon what is known as Clarke's scale, in which one degree of hardness implies one grain of bicarbonate or sulphate of lime in each gallon of water.

Water at and below about 6° of hardness is considered "soft" water, and above this range it would be styled "hard."

Hardness is of two kinds—(1) temporary or removable hardness, (2) permanent or irremovable.

Temporary hardness depends upon the presence of calcic and magnesic carbonates held in solution by carbonic acid (CO_2), with which it is loosely combined. When the CO_2 is drawn off, as it can be by boiling, the carbonates are precipitated and form a white deposit, giving rise to the "fur" found lining the interior of kettles and boilers.

Another method of precipitating the carbonates is the addition of such an amount of lime-water as will combine with all the CO_2 in solution, and so throw down both the carbonates originally contained in the water, and those formed by the union of the CO_2 and the added lime-water.

Permanent hardness is due to the presence of the sulphates of calcium and magnesium, and chlorides; also, in a minor degree, to iron, alumina, and free acid. Hardness of this kind cannot be removed by boiling

One grain of chalk (calcic carbonate) wastes 8 grains of soap, so that the total annual waste of soap for any given population using water of known hardness may be readily

calculated. In this way it has been estimated that the City of Glasgow saved something like £36,000 annually in soap by the introduction of the very soft water from Loch Katrine in the place of its former harder supply. The hardness of the water supplied to various towns differs very widely. The Glasgow (Loch Katrine) water is under one degree of hardness, that supplied to London about 16°, and that of the small town of Wellingborough (Northants) as much as 45° hardness. The water here is softened by Atkin's process.

The Softening Process by the addition of lime water indicated above was introduced by Dr. T. Clarke of Aberdeen in 1841; upon this principle the more recent methods are based. Among the towns using softening processes for their supplies may be mentioned Southampton, St. Helens, Stroud, Wellingborough, Saffron Walden, and others. The cost of softening varies from ¼*d.* to ¾*d.* per 1,000 gallons, and from 10° to 24° of hardness are removed. In the modified process known as the Porter-Clark method the lime is mixed with water by paddles and is then passed through filter presses of cloth, insuring a clear product and saving time and space. This process is specially adapted for waters of a high temporary hardness like those of London from the chalk. The following formations as a rule yield hard waters—Chalk, Upper Greensand, Oolites, Lias, Mountain Limestone, Coal Measures, and Devonian. Soft waters are obtained from the Bagshot Beds, Lower Greensand, Silurian, Metamorphic, and Igneous rocks.

Action of Water upon Lead.—The ill-effects of the action of some waters upon lead are now well known, and great trouble has resulted from this cause in connection with many water supplies, especially in the North of England. Lead possesses a cumulative poisonous action by which small quantities accumulate through the daily use of waters so tainted, until serious illness ultimately ensues. A blue line around the gums is an important characteristic symptom of lead colic or "plumbism" as it is called. It is very seldom that water in its natural state is tainted with lead, but it becomes so polluted in the course of distribution by contact with lead pipes, cisterns, &c. The soft moorland water of the Vartry attacked lead so readily that tin-lined pipes were used when the new supply was introduced in Dublin.

At Sheffield, too, a similar difficulty was experienced with a part of the supply where the water was peaty and of an acid character. The soft waters of Loch Katrine, however, gave little or no trouble in Glasgow. The waters which act most on lead are: (1) The purest and most highly oxygenated, such as rain-water, and the moorland waters of upland streams; (2) Those containing organic matter, nitrates, nitrites, and chlorides, such as water contaminated with sewage; (3) Waters containing a free acid, soft peaty waters as supplied to many towns in the North of England. Among those waters which act least upon lead are, hard waters containing carbonates, phosphates, and sulphates, especially carbonate of lime. Such waters soon deposit a protective coating on the lead surfaces. There are many other circumstances influencing the action of water on lead pipes. (1) It is affected by the length of time water is left to stand in the service pipes; (2) By the temperature of the water and the pressure under which it exists in the pipes, an increase of either favours the solution of the metal; (3) New lead piping is more easily dissolved than that which has been in use for any length of time; (4) The lead is more readily acted on if other metals, as iron, zinc, or tin, are in contact therewith, as galvanic action may be set up; (5) Bending a pipe against the grain and so exposing the structure of the metal increases the risk of solution; (6) Zinc pipes, into the composition of which lead often enters, yield lead in large quantities to the water. Water which has been standing in a lead service for a considerable time should be first drawn off before taking a supply for drinking purposes, should there be any danger from lead-poisoning. Filtration of the water through animal charcoal is a good plan to

insure freedom from lead. The charcoal, however, will require to be regularly renewed. New and bright lead is at first acted on by most waters until a protective coating has been formed on the surface. In cleaning out a cistern this coating should not be removed, neither should cleansing with acids be resorted to. The best material for a water cistern is slate. Both zinc and galvanised iron are affected, especially the former. The lead from the paint of internally painted cisterns is sometimes dissolved by the water. Portland cement makes a good surface, but is not a convenient material to use for household purposes. To detect lead in water a test may be made by putting one drop of sulphide of ammonium in a wine-glass full of water and stirring with a glass rod. The water will immediately discolour (black) if lead is present. In a valuable report by Dr. Houston on "Moorland waters in regard to their action on lead," submitted to the Local Government Board, and published in 1903, the whole question has received very exhaustive treatment. It is of great public importance having regard to the large proportion of the population of this country receiving water supplies from upland gathering grounds liable to yield waters of plumbo-solvent or erosive tendencies.

The Construction of Waterworks. — Systems of Supply.—The system of works upon which towns are supplied with water are usually classified either as "gravitation" works or "pumping" works; not infrequently it may be a combination or modification of both. In a gravitation supply, the water is usually obtained from a surface gathering ground, or catchment area, situate a considerable distance from the town to be supplied, and at such an elevation as will admit of the water derived therefrom being collected in an impounding or storage reservoir from which it may gravitate through perhaps several miles of pipe-line or aqueduct to a service reservoir situated near the town. The latter reservoir must also, in turn, be at such an altitude as will insure the supply being delivered to the tops of all the various buildings within the area of supply after having made satisfactory allowance for frictional losses of head in the distributing mains during times of heaviest draught. The general arrangement of such a system is shown diagrammatically in Fig. 3, in which the section from A to E illustrates the supply collected from the gathering ground A, into a storage reservoir B, passing, if necessary, through the filter beds and clear water tank below, and then gravitating through a pipe-line or aqueduct to the service reservoirs D, which are at a sufficient elevation to supply the town situated at E. It frequently happens, however, that small outlying parts of a water area may rise to a height above the top water line of the service reservoirs, and in such case the water for these limited districts must be pumped through this additional height, usually over a "stand-pipe" or into an elevated water-tank or tower situated upon the highest ground available, so as to command the tops of the highest houses within this area. In gravitation supplies, the works involved usually consist of any necessary preparation of the gathering ground such as the removal of dwellings, farmsteads, &c., where they may be likely to cause pollution, the formation of impounding or storage reservoirs in the lowest suitable part of the catchment area by the building of large earthen or masonry dams across the valley, the diversion into the main watershed of water from adjoining areas by means of pipe-lines or tunnels, the construction of the main aqueduct from the storage reservoir to the service reservoirs which should be placed near the town, and numerous accessory works incidental to the foregoing. The North and West of England and the country of Wales have excellent gathering grounds situate at high altitudes and subject to great rainfall. A great many towns in these parts have therefore naturally availed themselves of this excellent means of supply. Glasgow receives its supply from Lochs Katrine and Arklet, Manchester from Lake Thirlmere, Liverpool

from Lake Vyrnwy (North Wales), Bradford from Nidd Valley, and Birmingham from the Elan Valley in Mid-Wales. In the east and south-east of England such gathering grounds are not available, and the supplies are derived either from rivers, springs, or deep wells, sources which are, as a rule, at a low level with respect to the district to be supplied, and the waterworks therefore necessarily becomes a "pumping scheme."

Referring again to Fig. 3 it will be seen that if the ground rises from the point F in the section instead of descending, as in the gravitation section A to E, pumping will be necessary to raise the water the required "lift" through lines of rising main into high service reservoirs to supply the town at H. Other parts of the system such as storage reservoirs, filters, and clear water tanks may remain the same in either case.

In a pumping scheme there is usually less of what may be called heavy engineering work involved in the collection, storage, and conveyance of the water, but a large outlay is necessary in the provision of pumping machinery and buildings. The question of choice between gravitation and pumping schemes of supply often arises in practice. It will be obvious that no general statement of preference for one or the other could be made, as their relative merits will depend upon local conditions and the capital and working costs of each scheme. Generally speaking, the initial cost of a gravitation supply is greatest, but, on the other hand, against this is to be set the permanent annual expenditure of a pumping works. So that in cases where an ample supply of equal purity upon either system may be secured the question of cost will usually be the deciding factor.

The water supply of the Metropolis affords the largest example in the world of systems of pumping works, the water being derived from the Thames and Lea and deep wells in the chalk.

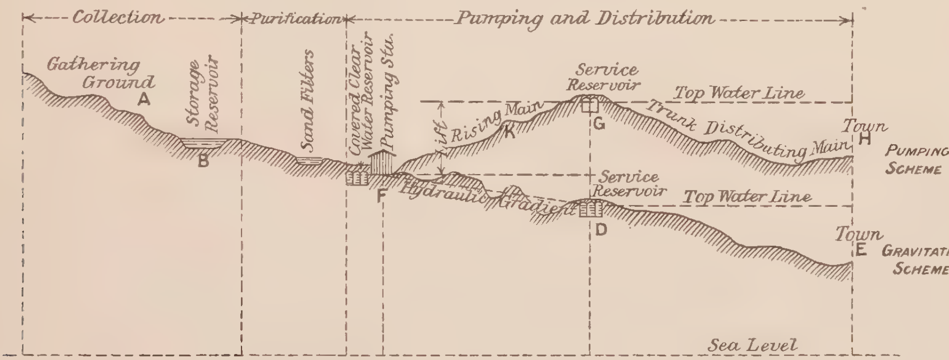


Fig. 3.—Diagram Illustrating Principle of Gravitation and Pumping Schemes.

Catchment Areas and Storage. — The extent of catchment area and storage capacity required for the supply of a town will depend mainly upon the quantity of water required daily, the amount of the annual rainfall and evaporation over that area, and the physical nature of the ground surfaces. It will be obvious that a much larger proportion of the total rainfall may be collected from a rocky and precipitous area than from one of a less hilly description or where a large amount of percolation may take place. Generally speaking, it has been found in England that the supply which can be relied upon from any definite gathering ground may be calculated by the formula :—

$$Q = 62{\cdot}15\ A\left(\frac{4}{5}R - E\right),$$

where, $Q =$ the daily supply in gallons.
$A =$ catchment area in acres.
$R =$ average annual rainfall in inches.
$E =$ loss of rainfall by evaporation in inches.

In England, the loss by evaporation amounts to from 10 to 18 in. in the year according to circumstances. Where no natural lake is available, as in the case of the Glasgow supply from Loch Katrine or the Manchester supply from Thirlmere, the water flowing from a gathering ground is stored up in the rainy season for use during the dry period, by forming an artificial lake or reservoir. This is done by constructing a masonry or earthen dam across the lower part of the valley of a mountain water-course. In providing such storage it is found to be unnecessary to thus attempt to equalise supply over a longer period than a consecutive three dry years' term, as by so doing there would be many years when the reservoirs would not get filled. The storage will also be regulated by the number of consecutive days in a dry time during which the supply might have to be drawn from the reservoir without any addition thereto. This period varies considerably in different districts, and depends upon the fluctuations of rainfall, the usual length of periods of drought, the amounts of percolation and evaporation, and other conditions, so that a much smaller storage would suffice in a wet district than in a dry one. For these reasons the storage provided may vary from about 70 to as much as 300 days' supply, but in England will mostly lie between a minimum of 100 days in wet districts and a maximum of 250 days in very dry districts.

Compensation Water.—In addition to the water obtained from a catchment area and stored in reservoirs, it is necessary to consider the question of compensation, payable only in water, to parties lower down the streams affected, in consideration of the flood water abstracted for purposes of supply to some distant town. To insure that the flow of the streams shall never be less than a certain stipulated amount, the daily flow of "compensation water" is fixed by the Act of Parliament authorising the construction of the works. It is clear that damage may result from such abstraction of water from streams, but, on the other hand, it is also equally certain that considerable benefit must accrue to riparian owners from the construction of impounding reservoirs mitigating the damaging effects of floods and equalising the flow of the streams throughout the year.

In practice, where the entire catchment area of a stream has been appropriated for the supply of an impounding reservoir, the amount of compensation water has been fixed at one-third of the average yield of the gathering ground in question. Formerly the proportion of an ordinary stream available for useful purposes appears to have been much over-estimated, and the conditions imposed in regard to compensation water were more onerous than are now proved to be necessary. Thus, in 1847, Liverpool was required to deliver one-half of the available yield from the Rivington watershed as compensation, and Manchester, in 1848, delivered two-fifths of the yield from the Longdendale area into the river Etherow. These have since both been reduced to about one-third of the available yield. The compensation water delivered by the Liverpool Corporation into the river Vyrnwy (Act, 1880) amounts to only about one-fourth of the yield of the catchment area, whilst that from the Thirlmere Works (Act, 1879) is only about one-tenth of the available annual yield of the gathering ground.

Leading Features of some Large Gravitation Supplies. — *Manchester*, in appropriating Lake Thirlmere for the purposes of supply, took powers to raise its natural level 50 ft., by building a concrete dam, faced with masonry, across its outlet, from the solid rock below up to a height of 57 ft. above the former level of the lake. By this means the area of the lake was increased from 328¼ acres to 793 acres, and a total volume of about 8,131 million gallons of water was impounded at a low cost. The storage is equal to a quantity of 32·6 in. over the whole catchment area, and is able to afford a supply of 50 million gallons a day for a period of 160 days. It is important, in this case, to have ample storage, as the total catchment area only amounts to 11,000 acres, or about 220 acres per million gallons daily supply. The rainfall, however,

in this district is large, amounting on the average of 18 years' gaugings to 85 in.; whilst the fall for three consecutive dry years is as much as 71 in. Owing to the steep rocky nature of the hill slopes the proportion of the rainfall reaching the lake is also large. The compensation water to be discharged amounts to 5½ million gallons a day. An aqueduct about 96 miles in length, and 7 ft. 1 in. wide by 7 ft. high where in tunnel, with pipe-lines where the invert falls below the hydraulic grade line, conveys the supply to the Prestwich reservoir, Manchester.

Liverpool had not the advantages of a natural lake at Vyrnwy, but by the construction of a concrete and masonry dam about 85 ft. high, above the river bed, across that river, impounded a storage of 13,000 million gallons for the supply of that city with a total daily quantity of 40 million gallons. A compensation water of 13⅓ million gallons a day, or one-third of the supply, was also provided. This was more than five times the dry weather flow of the rivers. The reservoir affords sufficient storage for about 220 days. The catchment area is 23,500 acres, or 588 acres per million gallons daily supply. The mean yearly rainfall for a term of 20 years from a large number of gauges was found to be 65·16 in., and the average fall of three dry years (1887-89) amounted to 54·58 in. The supply is conveyed to Liverpool by means of an aqueduct, 7 ft. in diameter in the tunnels and about 68½ miles in length, discharging into the service reservoirs at Prescot.

Bradford.—The new Nidd Valley works for Bradford provide an additional supply of 20 million gallons a day for that city, by impounding on the Upper Nidd a quantity of 2,596 million gallons from a catchment area of 18,200 acres. This gives a catchment area of 910 acres per million gallons daily supply. There is also a further gathering ground of 9,900 acres for compensation purposes. The rainfall, based on a 12 years' average, is 48 in. The dam forming the Gouthwaite compensation reservoir is of cyclopean rubble masonry in cement, and has a maximum depth from top water level to the foundations of 105 ft. Its thickness at the base is 70 ft. The water is conveyed from the Nidd Valley to the Chellow Heights service reservoir, a distance of 32 miles, in an aqueduct 5 ft. 6 in. wide by 6 ft. 3 in. high, with pipes across the valleys below the hydraulic grade line.

Birmingham.—One of the largest schemes of late years is that for the supply of Birmingham from the Elan Valley, in Mid-Wales. Here six large reservoirs are contemplated, having an aggregate storage capacity of 18,000 million gallons, capable of giving, for a period of 180 days, a supply of 75 million gallons a day to Birmingham, and a compensation water of 27 million gallons a day, or rather more than a third of the supply. The catchment area is 45,560 acres, or 608 acres per million gallons daily supply, and the average rainfall over a long term is about 70 in. The mean of three dry years is 56 in. The dams are of masonry and vary in height from 98 ft. to 122 ft. above the river bed. The aqueduct is 74 miles long and delivers into the Frankley reservoir, to the west of Birmingham.

Reservoir Dams for impounding storage water are constructed of masonry, concrete, or earth, and are dealt with under article "Dams, Earthen and Masonry."

Waste Weir, Bye-Channel, and Residuum Lodges.—The respective positions and functions of waste weirs, bye-channels, and residuum lodges are illustrated in the accompanying Fig. 4. A waste weir forms a very important accessory to every reservoir, and should be provided at a suitable place at the side of the reservoir. The sill of the weir should be at a slightly lower level than the highest proposed water level in the reservoir, so that any surplus water discharging into a full reservoir in flood time may escape over the weir and away through the waste water course to the natural stream below.

The length of weir required in any given case will depend upon what depth of water it may be considered safe to pass over it, which should ordinarily not exceed from 1 ft. to

18 in., otherwise the safety of the embankment may be endangered. The weir should therefore be made long enough to discharge the full quantity of flood water which the catchment area is calculated to send down, so that this influx may be readily conveyed away down the waste water course without raising the top water level of the reservoir above the limit proposed in the design of the embankment or dam. The length of weir in practice is very generally made from $2\frac{1}{2}$ ft. to 4 ft. per 100 acres of drainage area, varying according to the locality and rainfall of the district. In the case of an earthen embankment the waste weir should be formed in the solid ground at one of the extremities of the dam and not passed over any of the made earthwork of the bank. If the configuration of the ground is favourable the weir may sometimes be formed, with slight cutting, through some depression at the side of the reservoir and the flood waters thus removed as far as possible from the made bank.

In order to secure the greatest length of weir, and to reduce the amount of cutting, the weir is often formed curved in plan—the water, after passing over, falling by a series of flat steps, not exceeding 1 ft. rise with 3 ft. tread, into the upper part of the waste water course.

The Waste Water Course is designed to carry all the water flowing over the weir or coming down the bye-channel safely into the natural stream below. It therefore has a fall equal to the greatest depth of water in the reservoir, and, as the shortest route is usually selected for reasons of economy, its inclination frequently becomes very considerable. The waste water, therefore, must not flow down at such a velocity as will injure the stability of

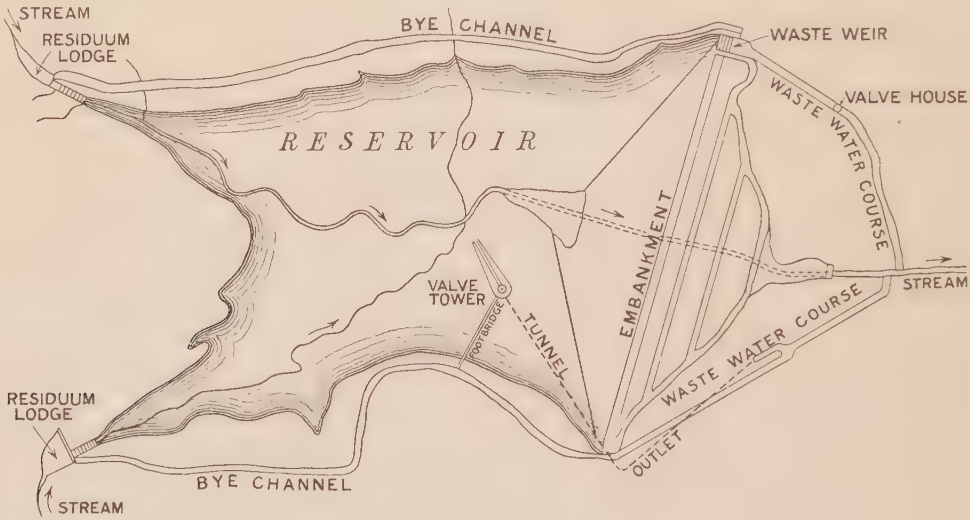


Fig. 4.—Plan of Reservoir, showing Waste Weir, Bye-Channels, and Residuum Lodges.

the work, although on grounds of safety and economy it is desirable to discharge it as quickly as possible. To check the velocity of flow a good plan is to form the waste water channel in a series of long shallow steps so constructed as to retain a pool of water on the top of each step, thus resembling a series of small weirs separated by pools, which have the effect of breaking up the impact of the falling stream. The steps shown in Figs. 5 and 6 are curved in plan with the view of increasing the stability of the work and the discharging power.

In the case of masonry dams the waste may flow over a portion of the dam itself by

terminating its crest at the top water level. The Vyrnwy dam is a good instance of this form of waste weir, and for this purpose the spaces under the 19 central arches between the piers carrying the roadway over the dam have been adapted, forming a weir 456 ft. in length. The surplus water thus falls down the outer face of the dam, which has been given a curved section to receive the shock of the falling water.

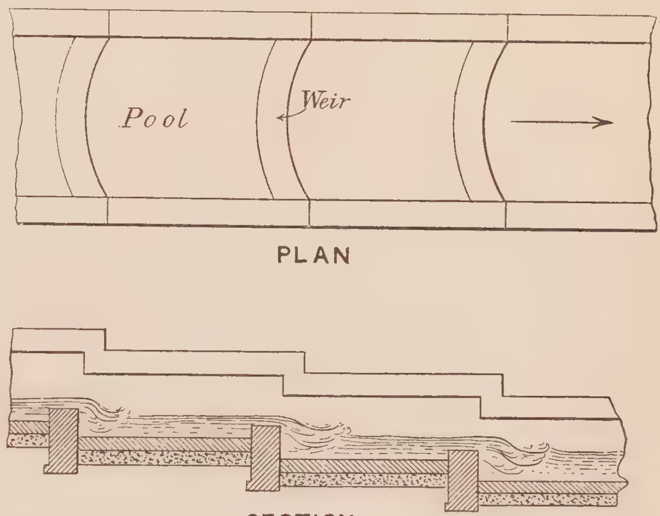
A Bye-Channel formed in cutting around the side of a reservoir, as illustrated in Fig. 4, is a necessary accessory work for the purpose of carrying away the flood discharge of the stream feeding the reservoir and for diverting the turbid and discoloured waters into the stream below the dam. It is also a great convenience as a by-pass during the construction of an earthen embankment.

These bye-channels are controlled by gates or sluices, and are lined along their sides and bed with puddle, concrete, or masonry, as circumstances may require, in order to prevent the erosion of the stratum through which they may be formed.

At the head of these bye-channels are formed small settling reservoirs termed "residuum lodges" or ponds (see Fig. 4) in which the sediment brought down by the flood waters is caught and deposited before the water passes on to the bye-channel or to the storage reservoir. These are provided with sluices or pipes for emptying them, and with movable shutters for diverting the water either into the bye-channel or reservoir, as desired.

Outlets from Reservoirs: Valve Towers.—Suitable means must be provided for drawing off the water stored in a reservoir for purposes of supply, and also for compensation, and as a considerable head of water has usually to be dealt with the treatment of the "outlet" requires to be carefully considered in order to avoid leakage of the water under pressure and consequent damage to the embankment or other permanent works.

Outlet culverts at one time were commonly laid through the base of the dam, at its lowest part, and thus afforded a convenient means of draining off the water coming down during the construction of the dam. Outlets so placed are, however, liable to be damaged by the unequal settlement of the embankment, especially at the point of passing through the puddle wall, and leakage of water under pressure is almost certain to result, leading to



Figs. 5 and 6.—Waste Water Course, with Pools.

subsidence and ultimately to the destruction of the dam. The prospect of failure is even greater when the valves controlling the discharge are placed at the outer end of the outlet, or in the centre of the embankment preventing access to the culvert for repairs. The outlet, whether consisting of a culvert or pipe, should be controlled throughout its length by a valve tower placed at its inner end within the reservoir.

The safest though most costly plan, where a reservoir is formed of an earthen embankment, is to carry the culvert through a tunnel round the end of the embankment, or through the side of the valley into another watershed

if the conditions are favourable, and to control the discharge by a valve tower within the reservoir, having inlets at different levels so that the water may be drawn off at various depths as desired. In the Villar masonry dam on the Lozoya for the supply of Madrid, and in the New Croton dam (New York), the outlets are carried through the dams at a low level with the valve chambers formed in the dam. A better plan, however, is to carry the culvert in a tunnel at one side of the valley beyond the dam, as done in the case of the Vyrnwy reservoir, where the flow is controlled and strained through copper wire gauze in a masonry tower built in the reservoir. The compensation water here is discharged by means of a culvert carried through the dam direct into the river below.

The proper arrangement of the outlet is a very important part of the design of a dam, and serious failures have resulted from unequal settlement near the culvert and infiltration of pressure water into the bank. The bursting of the Dale Dike embankment, near Sheffield, in 1864, on the occasion of the first filling of the reservoir was attributed to the unequal settlement and cracking of the puddle wall over the trench excavated in the rock in which the outlet pipes had been laid. Other causes contributing to this failure were the defective material used for the bank and the rough way in which it was raised, also the rapid filling of the reservoir. The embankment was 95 ft. high and the reservoir had a capacity of 114 million cubic feet.

Another instance of failure was the embankment across the Lynde Brook, Worcester, Mass., which burst in 1876 and released a reservoir of 110 million cubic feet capacity, owing to the gradual percolation of the water under pressure along the line of outlet pipes.

Valve Tower.—The outlet culvert from a reservoir is usually connected at its inner or upstream end with a "valve tower" which contains the supply and scour pipes, straining screens, and valves for working the outlet works of the reservoir. The tower is also provided with a vertical cast-iron pipe (an extension of the outlet pipe through the culvert) into which branches, controlled by valves worked from the valve chamber just above top water level, are connected in a manner enabling the water to be drawn off at different levels as may be required. The tower is usually circular in plan and is built of masonry, brickwork, concrete, or cast iron.

Siphon Outlets.—Where a reservoir does not exceed about 25 ft. in depth, the water

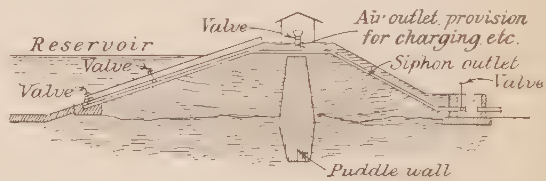


Fig. 7.—Siphon Outlet from Reservoir.

may be drawn off by a siphon pipe placed as shown in Fig. 7; that is, carried up the inner slopes of the dam, over the top, and down the outer slope to a lower level than the bottom of the reservoir. There must, of course, be sufficient difference of head between the two legs of the siphon to overcome friction and to give the required discharge. Water may be drawn off at any level by means of valves suitably placed on the inner slope as illustrated. To start the siphon the valves at both ends are closed and the pipe filled with water from the top of the embankment where a charging valve and air-vessel are placed. The discharge will be started by closing the valve at the top of the siphon and opening the others, but the summit must be kept free of air which will accumulate there and throttle the flow unless means are provided for its removal. The siphon may also be started by exhausting the air from the summit valve by means of an air-pump.

Siphon outlets have the advantage of not interfering with the embankment below high water mark, but they usually require a good deal of attention and are not generally satisfactory.

Creeping Flange or Puddle Collar.—The outlet culvert from a reservoir is stopped at some point in its length by a plug of concrete

or brickwork, through which the outlet pipe passes. The main passing through this plug should have cast upon it, or bolted around it, a deep projecting flange known as a "puddle plate" or creeping flange (Fig. 8) to prevent the leakage of water along the pipe.

Leaping or Separating Weirs are employed for the purpose of automatically rejecting flood waters from a collecting conduit. (*See article* "Leaping Weir.")

Aqueducts.—In a gravitation scheme the water is usually stored in a lake or reservoir formed in a valley situate in hilly ground at a considerable elevation above sea level, and also usually at a distance of many miles from the town to be supplied. The supply has, therefore, to be conveyed by means of an "aqueduct" to the service reservoirs in the immediate vicinity of the town, whence the water again flows by gravitation into the distributing mains, and is delivered at a pressure (depending on the relative heights of the service reservoir and of the area of distribution) sufficient to reach the uppermost storeys of the highest houses.

As formerly applied, the term "aqueduct" related more particularly to structures like the bold masonry bridges erected by the Romans for the conveyance of water across deep valleys, and to similar channels for purposes of irrigation and navigation. In its present

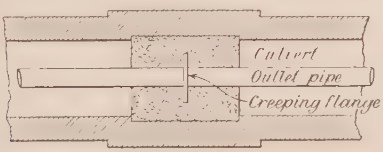


Fig. 8.—Creeping Flange, or Puddle Collar.

and more extended sense an aqueduct comprises, in addition to bridges, open or covered channels or conduits, tunnels, and metal pipe lines, now largely employed upon gravitation schemes of water supply.

The internal sectional dimensions of an aqueduct for the conveyance of a given volume of water will depend principally upon the "hydraulic gradient" which can be given to the conduit. The hydraulic gradient is expressed in feet or inches of fall per mile of length, and is the vertical fall between any two points on the line of aqueduct divided by the length. The hydraulic gradient may be maintained throughout if the aqueduct is constructed of the same cross section along its whole length, but it is frequently desirable to vary the gradient at different parts, on grounds of economy in construction, in order that the level of the work may be more nearly adjusted to the configuration of the ground or that the section of the tunnel, conduit, or pipes may be reduced in places.

An outline section of a modern aqueduct as constructed for a gravitation water supply scheme is given in Fig. 9, which represents the profile of the ground surface along the line of the aqueduct from Lake Vyrnwy to Liverpool.

Such aqueducts consist of a channel constructed to the inclination of the hydraulic gradient, and carried through hills or rising ground in tunnel; contouring hillside slopes or passing through fairly level ground in open cutting or cut-and-cover work; or, where the ground suddenly dips below the hydraulic gradient as shown at many places in the figure, the form of the aqueduct changes to a series of iron pipes laid side by side and following the contour of the ground surface with no greater depth of cover than is needed for protection against damage, instead of bridging the valley by means of a huge arched bridge following the hydraulic gradient as in the early Roman works. The pipe lines are of cast iron or riveted wrought steel tubes and form large inverted siphons, often many miles in length, through which the water flows under a pressure depending upon the depth at which they are laid below the hydraulic grade line.

The form of aqueduct at various points along the line will depend upon the configuration of the ground. Where this is fairly uniform, the hydraulic gradient will be followed by contouring the slopes in a more or less circuitous route, and the high ridges will be pierced by tunnelling, pipes

being resorted to only when a deep valley has to be crossed.

In the case of the above aqueduct it will be seen that the land mostly lies below the straight course, except at the points where the level rises above the hydraulic gradient (above which the aqueduct must not rise), and here tunnelling is resorted to and the invert of the

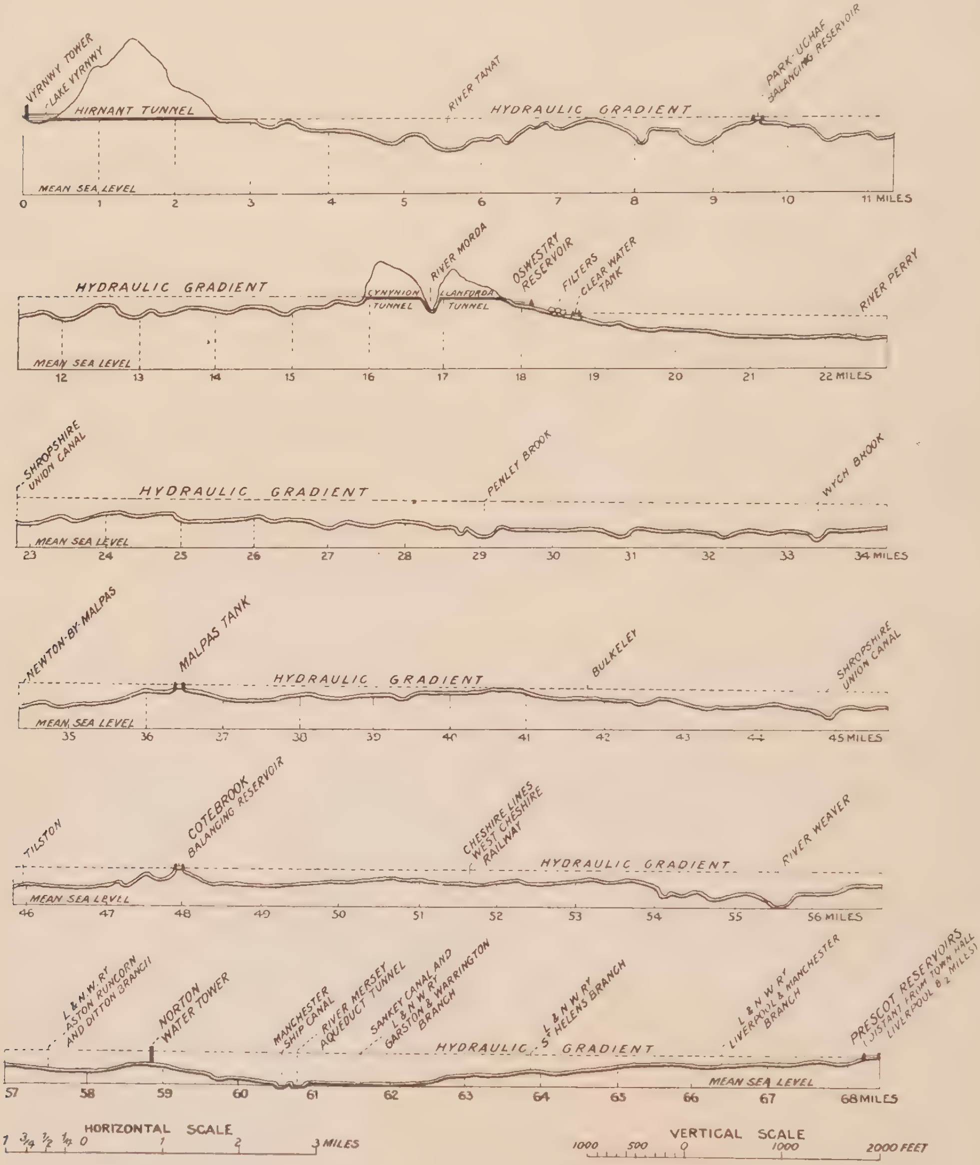


FIG. 9.—Vyrnwy Aqueduct. Longitudinal Section.

hydraulic grade line shortly after leaving the lake except at a point just before reaching Oswestry. In such a case the aqueduct consists mostly of pipes following the irregularities of the ground and following a fairly aqueduct coincides with the hydraulic gradient. The hydraulic gradient is also reached (see Fig. 9) at several points on the pipe line where "balancing reservoirs" are introduced for the purpose of reducing the pressure of

the water on the lowest part of the pipes by thus breaking up the fall of the aqueduct into independent sections.

The plan of following the hydraulic gradient usually involves a large amount of cutting for the conduit, and it frequently becomes necessary to follow a more circuitous route by contouring the hill slopes to avoid sudden changes of level in the ground, but balancing reservoirs are not required upon this method of constructing an aqueduct. Where a pipe line is adopted, a straighter and shorter course is obtainable and the available gradient is consequently greater. There is, however, a greater loss of head owing to the frictional resistance in the pipes, and a greater water section is therefore required for the same amount of discharge. In a pipe line, also, the pressure at the lowest point may become unduly great if not relieved by balancing reservoirs at suitable intervals.

Some of the most important aqueducts in this country for water supply purposes are the two from Loch Katrine to Glasgow (24 miles), from Thirlmere to Manchester (96 miles), from Nidd Valley to Bradford (32 miles), from Lake Vyrnwy to Liverpool (68½ miles), from Elan Valley to Birmingham (74 miles), and from Derwent Valley to Leicester (about 72 miles).

The Thirlmere aqueduct contains about 14·2 miles of tunnels, 36·75 miles of covered conduit, and about 45 miles of 48 in., 40 in., and 36 in. cast-iron pipes, laid as inverted siphons through the valleys. The siphon across the valley of the Ribble is 9½ miles long, and that across the valley of the river Lune has a dip giving a maximum head of water of 427 ft., equal to a pressure of about 186 lbs. to the square inch. The pipes are mostly carried over the rivers at the bottom of the valleys on bridges, so that they are readily accessible for inspection and repairs. For about 83 miles from Thirlmere a hydraulic gradient of 20 in. per mile is maintained, but in the remaining 13⅔ miles there is an available fall of about 32 in. per mile, and the diameter of this line of piping is consequently reduced to 36 in.

The siphons connect with the conduits through rectangular chambers formed at each end, and an automatic valve shuts off the supply in the event of the bursting of a pipe in the line of siphon.

The conduits are about 7 ft. by 7 ft. internal dimensions, and are formed of concrete on the cut-and-cover system with the portions in tunnel lined with concrete. The aqueduct is carried across small streams on masonry bridges, and a uniform gradient of 20 in. per mile is maintained.

The Vyrnwy aqueduct is divided into six sections by "balancing reservoirs" constructed on sites where the land attains the

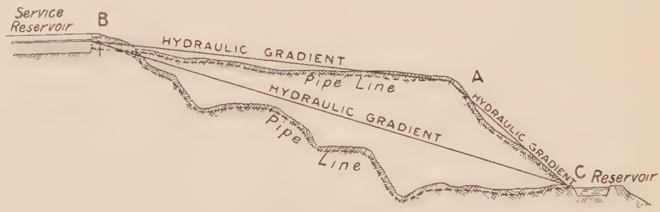


FIG. 10.—Hydraulic Gradient of Pipe Line.

level of the hydraulic gradient. It happened, however, that there was no land along the last 20½ miles of the aqueduct of a sufficient height to reach the hydraulic gradient, and it thus became necessary, in order to make a break in the long line of pipes under pressure between the Cotebrook Balancing Reservoir and the Prescot Service Reservoirs, to form a "balancing reservoir" on the top of a high tower, shown in the section (Fig. 9), on the summit of Norton Hill, situate about 3 miles to the east of Runcorn between the valleys of the rivers Weaver and Mersey. By this means the reservoir is raised to the hydraulic gradient, which at that point is 110 ft. above the surface of the ground. The reservoir consists of a circular basin 80 ft. in diameter, formed of steel plates, and having a central depth of 31 ft. The hydraulic gradient on this aqueduct varies from 2 ft. per mile in the tunnels

to 6·87 ft. per mile in the long siphon between the Oswestry reservoir and the Malpas tank. The pipe line will ultimately consist of three lines of pipes, and their diameters range from 32 in. to 42 in., according to the amount of fall available in the different sections. In the case of a burst pipe, automatic valves worked by the fall of a float gradually shut off the supply, and air valves fixed at all the summits of the siphons are provided for the escape of the air which otherwise accumulates in the mains at the high points and throttles the flow of the water.

The aqueduct from Elan Valley to Birmingham has a hydraulic gradient of only 15·84 in. per mile in the tunnels and conduits, but in the siphons the gradient is increased to 36 in. per mile, and will consist of six lines of 42 in. metal pipes. The total ultimate supply through this aqueduct is to be 75,000,000 gallons per day; that through the Vyrnwy aqueduct is 40,000,000 per day, and 50,000,000 from Thirlmere to Manchester. On the Elan aqueduct the longest siphon is 17 miles in length, and the greatest dip of the pipe line is 550 ft. below the hydraulic gradient, where the Severn is crossed by a bridge near Bewdley.

Service Reservoirs.—As mentioned already, the service reservoir is usually situate in the immediate vicinity of the town supplied, and is constructed upon the best available site of such an elevation as will be capable of delivering a supply of water by gravitation to the highest houses within the water area. Where a town consists of widely varying levels it is well to divide the water area into various high, middle, and low-level districts, or "zones" of supply, and to provide a separate reservoir for each if the conditions render such a system economical. By this means the cost of pumping to unnecessary heights will be avoided, as also the excessive pressures otherwise obtained in the lower parts of the town, which often cause much waste of water through weak or defective fittings.

The main objects of a service reservoir are, (*a*) to maintain a small storage of water near the town to provide against irregularities of consumption and to form a reserve to be drawn upon in cases of sudden demand, as the outbreak of fire, or to meet an emergency, such as the bursting of a rising main, the failure of an aqueduct, or of the pumping machinery delivering to the reservoir; (*b*) to give a fairly constant head on the supply mains, thus equalising the pressure therein, which cannot be secured by pumping directly into the mains; (*c*) to enable the pumping machinery to work at a fairly uniform and economical rate, and to avoid night pumping.

The rate of consumption of water varies according to the requirements of the town supplied and the extent to which trade and municipal supplies are connected to the system, but the demand is usually largest during the morning hours, commencing to increase at about 6 a.m., and reaching a maximum somewhere near 10 a.m. There will be various fluctuations during the remainder of the day, and the minimum supply will pass out during the night or early morning from 1 a.m to 4 a.m. By making a careful comparison of the quantity given out during these 4 hours a good idea of the percentage and variations in the daily waste may be obtained. On the average it is found that rather more than twice as much water is consumed between the hours of 6 a.m. and 6 p.m. as between 6 p.m. and 6 a.m.

A service reservoir should hold from 1 to 3 days' ordinary supply, or more if for any local circumstance the conveyance of water to the reservoir is liable to interruption. The reservoir is usually formed by excavating and building about half its depth below the ground surface and embanking the upper half above the ground line with the excavated material. The walls are built of concrete or brickwork, sometimes backed with clay puddle, and rendered internally with cement or bituminous sheeting. Seeing that the situation of service reservoirs is close to inhabited areas, they should nearly always be covered to prevent pollution of the water by dust, soot, or other objectionable matter, and the water is thus kept at a more uniform temperature,

cooler in summer, and less liable to frost in winter. The depth of the water therein should be not less than from 12 ft. to 15 ft., sufficient to impede the growth of animal and vegetable life.

There are many ways of covering reservoirs, amongst which may be mentioned a wood roof, with slates, concrete arches and piers, concrete arches or slabs carried by girders and joists, girders and jack arches, corrugated iron on light iron trusses, and expanded metal and concrete carried by girders and iron columns.

The various accessory details connected with a service reservoir include an inlet, outlet, overflow, scour or wash-out pipe, access ladder, manholes and ventilators, and water-level indicator. A good plan is to surround the inlet by a dwarf wall to retain a small quantity of water which will act as a cushion for the incoming water to fall upon. The outlet should be a few inches above the level of the floor and guarded by a close wire screen. Manholes for access and light during cleaning and repairs should be provided, and the reservoir should be well ventilated. The water level in the reservoir is now very generally recorded by means of an electric water-level indicator connected direct with the pumping station or the water engineer's office. It is a good plan to have a large reservoir divided by means of a dwarf wall so that one-half may be used for maintaining a constant head on the supply mains whilst the other half is under repair or being cleaned.

Circular reservoirs are more economical to construct than rectangular ones, as the thickness of the walls may be much reduced. Taking the thickness of straight walls in rectangular service reservoirs as varying between one-fourth and two-fifths of the depth, those of circular reservoirs have been found strong enough with a thickness of from one-sixth to one-tenth of the depth. In construction, circular reservoirs will be found to be from 20 to 40% cheaper than those of a rectangular design, but are not, of course, so economical in ground space.

The cost of a covered service reservoir varies from about £2 up to as much as £10 per 1,000 gallons capacity, depending very largely upon local circumstances and the size of the reservoir. About £5 per 1,000 gallons may be taken as a fair average price under ordinary conditions.

Concrete, when made of good clean materials, is a very useful material for the construction of a service reservoir. A circular reservoir of 550,000 gallons available capacity formed of this material at Upwey for the Portland Urban District Council was built entirely of concrete composed of 6 parts Moreton gravel to 1 part of Portland cement. The reservoir is 90ft. internal diameter with a depth of water of 16 ft. The external wall is 3 ft. thick, and the floor, which slopes towards a wash-out pipe, is 1 ft. in thickness. The roof is of concrete arches of 8 ft. clear span and 1 ft. thick, and is carried by eight cross walls 1 ft. 6 in. thick pierced with openings 10 ft. by 8 ft. The internal surfaces are rendered with two coats of Portland cement mortar, the first coat, $\frac{3}{4}$ in. thick, being composed of 1 part cement to 2 parts sand; and the second coat $\frac{1}{2}$ in. thick, of 1 part cement to 1 part sand, and trowelled to a hard smooth surface. The reservoir is well ventilated, and lighted from the crown of the arches, and a valve chamber is formed outside the reservoir through which passes the rising and delivery mains. Water is admitted to and flows from the reservoir by a floating arm, and is thus always drawn from about 9 in. below the surface so that no sediment or floating matter can enter the supply mains. A Jennings' patent electrical mechanical indicator and recorder is fixed at the pumping station, and is electrically connected with the reservoir, so that the quantity of water in the reservoir is always known to the man in charge at the pumping station. This reservoir cost £2,270, or £4 2*s.* 6*d.* per 1,000 gallons.

Distribution of Water.—A water supply, having been delivered to a service reservoir of sufficient elevation to command the area of supply, is distributed by means of cast-iron lead-jointed mains throughout the water area.

The first consideration is to decide upon the best routes and determine the requisite sizes of the leading trunk mains, having due regard to the elevation of the various streets to be supplied, and the present and future population to be connected thereto. For branch mains supplying a single street, 3 in., 4 in., or 5 in. diameter pipes will usually be sufficient, but the sizes of leading mains will vary considerably according to the districts fed by them, and each case will involve special investigation.

Where there is no special provision in the way of a subway under a street, a good position for the water main is in the roadway at a distance of about 3 ft. from the curbing. The mains should be laid with a minimum of 2 ft. 6 in. or 3 ft. of cover as a protection against frost and damage from heavy traffic, and the pipes should be thoroughly well coated with Dr. Angus Smith's solution or other like preservative and have a thickness of metal adequate for the water pressure to which the pipes will be subjected.

Whilst some distinction might be made in the thicknesses of metal between two entirely separate zones of supply having widely varying pressures, it will be unwise to attempt to differentiate between the pressures of the same area, otherwise great confusion may easily arise for the want of standard sizes in the spigots and sockets of pipes, and thus lead to much inconvenience and delay in the execution of repairs. Another objection to reducing the standard thicknesses is that water at a higher pressure may upon an emergency, such as a fire, require to be turned into the low pressure district. In very wide streets with much traffic it is not unusual to have a large leading main near the centre of the roadway with smaller tapping mains on each side in or near the footpath, to which are connected the house supplies, thus leaving the trunk main exclusively for the supply to districts beyond. The pressure in the leading main is thus maintained and the inconvenience and cost of crossing the street to make house connections is avoided.

In laying out a distribution system it is important to provide adequate main capacity, bearing in mind that it is the maximum summer supply during any hour of the day which must be provided for and not the average of the year, month, or week. The maximum rate of draught may be taken approximately at double the average consumption of 24 hours, and mains must be of sufficient capacity to deliver the requisite quantity at the required pressure during all periods of the day. In long lengths of small-sized mains the frictional losses at the time of heaviest draught will be considerable, and the size of the mains should be such that not more than about one-fourth of the available statical head should be consumed in overcoming friction.

In addition to the ordinary supply it must be remembered that a heavy draught will also be made at times for street watering purposes and that this usually occurs at the time when domestic supplies are at a maximum. It is necessary, therefore, that the pressure should at all times be sufficient to reach the highest storeys of premises within the distribution area.

In districts where there is great variation of levels it usually becomes necessary to divide the area into separate districts or "zones of supply" so as to maintain pressures in the mains suited to these different areas, otherwise an excessive pressure will obtain in the lower areas. As a maximum pressure a head of about 200 ft., equivalent to 86 lbs. to the square inch, may be adopted. Water fittings in general use will not satisfactorily withstand a head much beyond this figure under ordinary working conditions without great waste of water. The different zones of a district, usually designated "high-level," "middle," and "low-level" according to circumstances, are supplied by means of service reservoirs, water-towers, and stand-pipes suitably placed to command the various levels.

A "stand-pipe" supply is given by placing a vertical pipe (in the form of an inverted U) in the line of rising main, and the water is pumped against the additional head due to the height of the stand-pipe, and a corresponding

increase of pressure is thus afforded for houses lying at a greater elevation than the service reservoir. The surplus water passing over the top of the stand-pipe falls through the down leg and enters the service reservoir. Where a considerable area at the higher level has to be supplied it is preferable to have more high-level storage than is afforded by a stand-pipe, and for this purpose a "water-tower" is substituted (*see* "STAND-PIPE AND AIR-VESSEL").

By zoning a district in this way the cost of raising the whole supply to one high-level reservoir is avoided, and the pressures are maintained more uniformly throughout, but some additional complication and expense may be involved in the daily working of the different levels, so that it becomes desirable to confine the number of zones within the limits of absolute necessity.

In laying out a pipe line, care should be taken that no part of the line rises above the mean hydraulic gradient or the discharge will be impaired or perhaps be nil. The hydraulic gradient is represented by a straight line drawn from the point where the water enters the pipe line (as *B*., Fig. 10) to the termination of the line at its point of discharge, *C*. When the pipe line is below the hydraulic gradient the discharge at *C* will be that due to the hydraulic gradient *B C*. If, however, the ground rises to a point such as at *A*, the hydraulic gradient *B C* will no longer govern the discharge, which will be limited to that due to the flatter gradient *B A*. The remaining and steeper portion *A C* of the pipe line *B A C* may therefore be of a less diameter than that from *B* to *A* to give an equal discharge. It is therefore readily seen that the section of a line of main should be plotted and the hydraulic gradients obtainable well considered before the sizes of the different sections of a pipe line are finally decided upon, otherwise an insufficient discharge may result or an unnecessary expense may be incurred by continuing a main of large diameter when one of a smaller section would have proved adequate.

The delivery of water mains of various sizes and hydraulic gradients is obtained in practice from hydraulic tables based on the results calculated from empirical formulæ arrived at by various experimenters in hydraulic science. Space will not permit of more than a mere mention of the subject here, but reference should be made to works specially devoted thereto.[1] The formula now commonly used is Herr Kutter's, which gives more correct results than the older formulæ and takes into account the degree of roughness of the internal walls of the pipes. Speaking generally, the difference between Kutter's and the older formulæ is that it gives smaller discharges for small diameters, and larger discharges for large diameters.

INTERMITTENT SUPPLY.—Water supplies were formerly delivered to consumers at short intermittent periods of the day, during which the storage cisterns of dwelling-houses were filled for the use of the household until a further supply from the main was again available. The object of the system was to prevent waste and to economise water, but there were many drawbacks to this method, particularly from a sanitary point of view, and it has now become almost obsolete. The principal objections to an intermittent service are—(1) the storage of considerable quantities of drinking water oftentimes in more or less unsuitable and dirty receptacles; (2) the risk of pollution of the water owing to the mains and service pipes being alternately empty and charged, thus producing at times an inward suction in the case of leaky pipes. The intermittent system is seldom resorted to at the present day except under absolute necessity during periods of shortage of water.

CONSTANT SUPPLY.—The efforts of water

[1] "Water-pipe Discharge Diagrams" (Kutter's formula), by E. B. & G. M. Taylor, Civil Engineers (published by B. T. Batsford). "Hydraulic Tables," by P. J. Flynn, Civil Engineer (E. & F. N. Spon). "Practical Hydraulics," by Thomas Box (E. & F. N. Spon). "Tables for the Solution of Ganguillet and Kutter's formula," by Col. E. C. S. Moore, R.E. (B. T. Batsford).

authorities are now invariably directed to the maintenance of a "constant supply" of water in the mains at a good pressure, so that water may be drawn by the consumer direct from the main. Occasional temporary interruption under this system occurs only during accidental bursting of a main, repairs, or alterations. To meet such emergencies it is advisable that the consumer should be provided with a small storage in well-covered cisterns made of slate, galvanised iron, or other suitable material. Cisterns should, however, be placed in a position readily accessible for inspection and cleansing. In addition to taps drawing from storage cisterns, each consumer should also be provided with a tap for general use, taking its supply direct from the main. The introduction of a constant water supply service at good pressures has involved the necessity for superior types of water fittings in order to prevent waste and misuse of water. All such fittings should be subject to the approval of the water authority, and be tested and stamped before being passed for use.

Prevention of Waste.—The extent to which expense may be usefully incurred in the prevention and detection of waste is a problem requiring the careful consideration of the waterworks engineer. The value of the water thus lost must be balanced against the cost of the detection and prevention of the waste. Where the first cost of the water is considerable, or the quantity limited, the introduction of means to prevent waste will be well repaid by the saving thus achieved, as leakage and careless waste, if unattended to, are liable to become so serious in the aggregate as to materially increase the annual cost of supply, particularly where the water has to be pumped. Moreover, the saving of waste enables the supply to be extended to a larger area, and tends to defer the time when it will be necessary to expend further capital in augmenting the sources of supply. One of the principal means of detecting and localising waste is by the application of Deacon's waste-water meter system, first introduced at Liverpool in 1873-75. In this system the distribution area is subdivided into small districts containing from 2,000 to 3,000 consumers, and a waste-water meter fixed in a by-pass pipe on the distributing main supplying this district at a point where this branch main leaves the primary main, so as to isolate the supply to the sub-district by passing it through the meter. The meter contains a revolving drum upon which is automatically recorded the quantity of water passing into the district. If, during some portion of the night or during the small hours of the morning, the consumption so recorded is larger than is reasonable for that period of the 24 hours, it may be safely inferred that some unusual draught is taking place either through waste in the main itself or in household fittings. The investigation is then followed up by an examination of the sub-district during the night, and each stop-cock to the separate premises supplied is sounded by using the valve-keys as stethoscopes, and any sound indicating passage of water is carefully noted and traced to its origin as far as possible. Premises into which water is thus noted to be passing are examined internally on the following day, and by these means the location of waste is speedily effected. Much time is thus saved in house-to-house inspection, as the diagrams from many of the sub-districts of a large town may show the conditions to be normal and that no material waste is taking place, thereby enabling the time of the inspectors to be concentrated upon those areas in which the waste is shown to be greatest.

Fire.—The demand upon the water distributing system for fire purposes is a very variable and uncertain one. Much depends upon the class and density of the property to be served. In the case of fully-built-up districts in a crowded city with high buildings, offices, and warehouses containing more or less inflammable stock, a liberal allowance in main room capacity must be made. Consideration must be given to the elevation of the property served with relation to the level of the service reservoir and the pressure available at the fire hydrants when discharging through the

requisite length of hosing. It is also important to have regard to the probable maximum number of hydrants likely to be in use at the same time, and the main room provided should be such that the water pressures will be well maintained when the maximum number of hydrants is in use. For fire purposes $2\frac{1}{2}$ in. diameter canvas hosing is commonly employed, and the loss of pressure due to friction in traversing long lengths is very marked. In cases of large and important buildings, especially where there are a large number of occupants, several hydrants will necessarily be in use at the same time, and if a satisfactory supply is to be afforded, the volume of the main must be increased to meet such an emergency. In elevated situations where the ordinary pressures in the mains is insufficient to throw a jet of water to the top of a building, the water may usually be more advantageously used through a fire engine, and the capacity of the mains should be adjusted to meet such a demand. In districts where the water is pumped direct into the distributing system, ample stand-by power should be provided, and the fire brigade headquarters should be in direct telephonic communication with the pumping station so that immediate notification of the outbreak of fire can be transmitted thereto by the fire authorities. The spacing of hydrants will require consideration in regard to the properties to be served; thus in busy town centres they are often placed from 50 to 100 yards apart, and from 100 to 150 yards in residential quarters. Important corners and cross-roads will require special provision according to circumstances.

Cast-Iron Pipes for water supply purposes are usually made in 6 ft. lengths for 2 in. and $2\frac{1}{2}$ in. diameters, 9 ft. lengths for 3 in. to 10 in. diameters, and 12 ft. lengths for 11 in. diameter and upwards. The pipes should be suitable for a working pressure of about 300 ft. head of water, and should be tested to a proof strain of not less than 600 ft. This margin is necessary owing to the varying pressure to which the pipes are liable during their lifetime, such as sudden shocks and "water hammer," as may be caused by turning the water off too suddenly or by air in the pipes giving rise to concussion. For these pressures the thicknesses of metal for 2 in., 3 in., and 4 in. should be $\frac{3}{8}$ in., for 6 in. diameter pipes $\frac{7}{16}$ in., for 9 in. diameter $\frac{9}{16}$ in., and for 12 in. diameter $\frac{5}{8}$ in.

Ample initial strength is also necessary owing to the deterioration of the pipes after being laid in the ground, where they are liable to decay and oxidation, thus, in the course of years, materially reducing their thickness. Carbonaceous matter, such as cinders, will, with moisture, eat into or "pit" the surface of the pipes laid in this material. Very soft waters also tend to cause deterioration by oxidation and incrustation.

Cast-iron pipes should be tested to the pressures above named before leaving the foundry, and should sustain the test for several minutes, being struck at the same time with a hammer so as to produce a strong vibration. Specimen test bars and rods of the metal employed in the casting of the pipes are also very usually required to be submitted by the founders for testing the transverse and tensile strengths. The straight pipes are cast in sand moulds placed vertically, and the special castings in close boxes. The thickness of the metal should be as uniform as possible and the weights of the pipes in the small diameters should not vary more than from 3 to 4 °/ₒ. As soon as the pipes have been proved, and before they are attacked by rust, they should be coated externally and internally with a preservative composition such as Dr. Angus Smith's solution. The pipes are heated to from 300° to 400° F. and dipped in a mixture of the composition approaching boiling point, thus forming a protective coating on the metal.

Water mains should be jointed with the best soft blue pig lead and well caulked. The joint should be run in one running so as to insure the whole joint being homogeneous. To prevent the lead passing into the insides of the pipes, and to economise the quantity of lead used, the joint is first caulked with

yarn, then run with lead, and afterwards set up.

On all distributing mains a very important fitting for the proper control of the supply is the *sluice valve*, of which a large number are always required. These valves should be double faced, having two gun-metal faces on the body of the valve and two on the valve door. The valve spindle and nut are also of gun-metal, and the gland and stuffing-box bushed with gun-metal. In a district of supply it is important that all the valves should open the same way, as if some are left-handed and others right-handed trouble will arise through the valves being shut by mistake. All valves should be subjected to a hydrostatic pressure of 600 ft. of water as a test before use, and should be coated similar to the cast-iron mains described above. Screw-down valves have the advantage of shutting off the main gradually and preventing concussions. A *plug-cock* should not be inserted in a water main, as its sudden closing would have a very damaging effect. Large sluice valves on leading mains should be provided with indicating wheel gearing to show when full, half open, or closed. It is difficult to start opening the door of a large valve when the pressure is on one side only, and to overcome this trouble a small by-pass pipe with valve or stop-cock is provided, communicating with each side of the large valve for the purpose of charging up the main before opening the larger valve. Leading supply mains and pumping mains should be fitted with self-acting *air escape valves* placed at every high point on the line of main for the escape of air which otherwise accumulates at these points. Air pipes of about $\frac{3}{4}$ in. diameter controlled by a full-way cock are also sometimes provided for releasing large quantities of air when a main is being re-charged after emptying. But little difficulty is experienced from the accumulation of air in the branch supply mains as a rule, as the continual draught on these mains by the house services allows of the ready escape of air.

Other varieties of waterworks apparatus and fittings in general use for the distribution of water include different classes of fire hydrants, stand-pipes, street watering posts, drilling apparatus for connecting to mains, tapping ferrules, stop-cocks, bib-taps, ball valves, bath and lavatory fittings, flushing cisterns to w.c.'s, automatic flush tanks, and surface boxes for hydrants, meters, &c. Of these it may be said, generally, that the best types are usually those which are the simplest and strongest in design and construction, and that whilst a very good idea of their great variety and design may be gathered from an inspection of the various makers' catalogues, experience in their use under ordinary every-day conditions is the best means of finding out what good points of design are to be looked for and what weak points are to be avoided in the selection of fittings of this kind.

Water Service Pipes communicating between the supply main and the premises to be supplied should not be less than $\frac{3}{4}$ in. internal diameter, and should be made of strong well-galvanised iron piping, or, in the case of a hard water, they may safely be of lead. The pipes must be capable of withstanding an internal pressure of from 400 ft. to 600 ft. head of water, and should be laid in the ground with not less than 2 ft. of cover so as to protect them from damage by frost or other cause. Every house should be provided with a separate service pipe, which should be connected with the main by means of a brass screw stop ferrule. A stop-cock is inserted in the service pipe near the point of entrance to the premises supplied and on the footpath wherever possible. A tap should also be inserted in the service pipe for the purpose of completely emptying the pipes in case of frost or repairs. The drawing and stop-cocks should be of the screw-down pattern, of the best make, and be tested and stamped by the water authority before use. All soldered joints on lead pipes should be of the kind known as "plumbers'" or "wiped" joints.

Overflow or "warning pipes" from cisterns

should be so placed that the overflow may be readily detected and should not be discharged into gutters, rain-water pipes, lead flats or roofs, otherwise a waste of water may be allowed to continue for a considerable time before being remedied.

The regulations of water authorities usually stipulate that w.c.'s., urinals, and boilers should not be supplied direct from the mains, but from separate cisterns. Water-waste preventers attached to w.c.'s and urinals should be capable of discharging 2 gallons of water in each complete flushing operation in 15 seconds. Such apparatus should be of a type approved by the water authority, and should be capable of discharging their contents rapidly and with certainty, so as to secure the full benefit to be derived from the effect of the flush. A continuous running dribble of water is of no practical use for flushing purposes, and is extravagant and wasteful. To prevent waste, baths should be fitted with a water-tight plug outlet attached to a chain. Ball-taps for cisterns should be tested and proved water-tight under a pressure of, say, 300 lbs. to the square inch, or according to the maximum pressures likely to be experienced from the mains. With proper regulations and adequate supervision, water authorities are enabled to check much waste and misuse of water, such as frequently arise from the employment of inferior fittings.

Dual Supplies of Water.—The difficulties of obtaining within a reasonable distance suitable supplies of pure water (in sufficient quantity) is yearly increasing with the growth of population, and the question is often discussed as to the advisability of introducing dual supplies of water, using the purer sources for all dietetic purposes, and employing a less pure and cheaper water for street watering, sewer and drain flushing, and certain trade purposes. Several seaside towns in this country have installed plants and mains for the use of sea-water for municipal and other purposes, but the results, speaking generally, can scarcely be considered a success, and in some cases the system has been abandoned altogether. The dual system of supply has been followed out to a considerable extent in Paris, where the water for domestic purposes is drawn from natural springs in the chalk in the basin of the Seine and brought to the city in three closed aqueducts, viz., the Dhuis, the Vanne, and the Avre, and discharged into covered service reservoirs; whilst the supply for the streets, gardens, stables, yards, and trade purposes is obtained from the river Seine, the Marne, and the canal of the Ourcq, and other sources, including artesian wells. The double system is, however, not favourably reported upon.

The use of two waters obviously involves the laying down of a double set of distributing mains, thus greatly increasing the cost to the water undertaking, and also greatly adding to the complications of the supply and increasing the risk of mistakes in making connections with the mains. When the increased initial cost is taken into consideration, together with the annual expenses of the upkeep of two supplies, the advantage of such a system is very doubtful, unless some purely local conditions in a given case operate powerfully in its favour.

Water Main Scraping.—Mains which have become much reduced in discharging capacity are sometimes cleansed by introducing a "scraper" into the main through special "hatch-boxes" provided thereon, and forcing the same forward by applying water pressure behind it. The process, however, is frequently a troublesome operation, owing to the scraper occasionally becoming fixed at a bad joint or bend in the main, involving, in some cases, the cutting of the main in order to remove it. Scraping is not often attempted on mains less than 6 in. in diameter. The average cost of scraping appears to be about ·75*d.* per yard per inch of diameter of main, including wages, lead, yarn, hatch-boxes, and scraper, but the plant having once been purchased, subsequent scraping costs should be comparatively small.

For further information upon "water supply," reference should also be made to the

following articles :—"Abyssinian Wells"; "Algæ in Water Supplies"; "Artesian Wells"; "Bacteriology of London Water Supply"; "Bore-wells"; "Catchwater Drain"; "Cholera"; "Dams"; "Effluents"; "Filters (domestic)"; "Filtration (mechanical)"; "Filtration (through sand)"; "Fish Life in Streams"; "Frost (effect on water fittings)"; "Gauging of Streams"; "'Head' of Pressure, loss of"; "Hydraulic Memoranda"; "Hydrostatic Head"; "Intake"; "Lateral Water Filtration"; "Leaping Weirs"; "Local Government Board Requirements (water supply)"; "London Water Supply"; "Meteorology"; "Micro-organisms in Water"; "Ozone"; "Pipes, Cast-iron, &c."; "Plumbing"; "Pumps and Pumping Machinery"; "Rainfall"; "Rain-gauge"; "Rising Mains"; "River Boards"; "Rivers, Purification of"; "'Separator' for Rain Water"; "Siphon"; "Stand-pipe and Air-vessel"; "Sterilisation of Water"; "Suction of Pumps"; "Typhoid"; "Underground Water"; "Valves (water supply)"; "Venturi Meter"; "Water, Analysis of"; "Water, Odours and Tastes"; "Water Meters"; "Watershed"; "Water, Sampling of"; "Water Supply (domestic)"; "Water Supply, Royal Commissions on"; "Wells."

W. H. M.

Water Supply, Royal Commissions on.—During the past 40 years the question of water supply has been under consideration by a number of Royal Commissions, Select Committees, and others. The following are the dates of the appointment of the various Commissions, and of their reports :—1866, Royal Commission on Water Supply: Chairman, the Duke of Richmond, K.G.: reported 1869; 1868, Rivers Pollution Commission (replacing Commission issued in 1865): reported 1874; 1872, reports by Mr. William Pole, "On the Constant Service System of Water Supply"; 1879, Parliamentary "Return showing the means by which drinkable water is supplied to every Urban Sanitary District in England and Wales"; 1880, Select Committee on London Water Supply; 1884-5, Select Committee of House of Lords on Water Companies; 1892, Royal Commission on Metropolitan Water Supply: Chairman, Lord Balfour of Burleigh: reported 1893; 1897, Royal Commission on Water Supply within the Limits of the Metropolitan Water Companies: Chairman, Lord Llandaff: reported 1898 and 1899; 1900, Select Committee on Local Authorities' Reproductive Undertakings. The question has also been dealt with on several occasions in connection with Bills for the water supply of the Metropolis and other towns.

Duke of Richmond's Commission, 1866.—The Commissioners were directed to ascertain what supply of unpolluted and wholesome water could be obtained by collection and storage in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs, at a sufficient elevation for the supply of the large towns, and to inquire into the existing water supply to the Metropolis. They soon found that an inquiry into the supply of the provincial towns would be one of great magnitude and would probably occupy several years. They therefore confined their attention almost exclusively to the more pressing question of the supply to London. After considering various proposals to bring water from Wales, the Lake District, and Derbyshire, they expressed the opinion that the water from the rivers Thames and Lea, together with that obtainable from the chalk and lower greensand, would suffice to supply any probable increase of the Metropolitan population; that there was no evidence to lead to the belief that the water supplied by the companies was not generally good and wholesome; that its quality depended on perfect filtration; and that artificial softening did not appear to be applicable to the Thames water. They expressed strong opinions in favour of the system of constant supply, and of the control of water undertakings by local authorities. Doubts are cast on the reliability of gravitation supplies to large towns from catchment reservoirs in hilly districts, and it

is strongly recommended that no town or district should be allowed to appropriate a source of supply which naturally and geographically belongs to another. This report was issued on 9th June, 1869.

Rivers Pollution Commission, 1868.—Meanwhile the question of water supply was also being considered by the Rivers Pollution Commissioners, Dr. Edward Frankland and Mr. John Chalmers Morton, having been entrusted to the original Commissioners in an instruction dated 7th July, 1865. Their sixth and final report, issued 30th June, 1874, deals exclusively with this question, and constitutes a most valuable and exhaustive review both of the existing supplies and of the available sources throughout the country. The following is their classification of waters in order of merit:—

Wholesome	1. Spring water (5)	Very palatable.
	2. Deep well water (6) ..	
	3. Upland surface water (2)	Moderately palatable.
Suspicious	4. Stored rain water (1) ..	
	5. Surface water from cultivated land (3)	Palatable.
Dangerous	6. River water to which sewage gains access (4)	
	7. Shallow well water (7) ..	

The numbers in brackets give the positions of the various waters in order of softness. Excessive hardness is condemned, and, for waters possessing it, artificial softening is recommended. Soft and moderately hard waters are referred to as equally wholesome. The Commissioners state emphatically that no river in the United Kingdom is long enough to secure the oxidation of sewage which may be discharged into it, and that no process which had been proposed down to that time could be relied on to purify polluted water. The protection afforded by sand filtration against the propagation of epidemic diseases by water is characterised as "feeble." The Commissioners therefore recommend the early abandonment of the Thames and Lea as sources of water for domestic purposes in the Metropolis, and the exclusive use of spring and deep-well waters from the London basin softened with lime. Whenever circumstances compel the taking of a water supply from a polluted river, storage reservoirs are recommended of sufficient capacity to render unnecessary the intake of water during floods. The water supplies of the Royal residences are specially reported on.

Royal Commission on Metropolitan Water Supply, 1892.—Lord Balfour's Commission reversed the finding of its predecessors recommending the abandonment of the Thames and Lea, and expressed a strong opinion that the water supplied to London was "of a very high standard of excellence and of purity, and . . . suitable in quality for all household purposes." With regard to the prejudice which exists against these waters on the ground of sewage pollution they observe: "We do not believe that any danger exists of the spread of disease by the use of this water, provided that there is adequate storage, and that the water is sufficiently filtered before delivery to the consumers." They were also of opinion that a sufficient supply for the wants of the Metropolis might be found within the valleys of the Thames and Lea for a long time to come. They recommended the exercise of all possible vigilance to prevent unnecessary contamination of these rivers and their tributaries, the construction of adequate storage reservoirs, and the keeping of accurate observations on the effect of pumping from the chalk upon the water levels in the wells in that formation.

Royal Commission on Water Supply within the Limits of the Metropolitan Water Companies, 1897.—The first report of Lord Llandaff's Commission dealt exclusively with the question of intercommunication between the systems of the different Metropolitan water companies. Their second and final report was of a more general character. In the latter they expressed a general approval of the findings of Lord Balfour's Commission as regards the suitability and adequacy of the existing sources of supply to London. They examined the proposals

brought forward by the London County Council for obtaining a supply from Wales and dismissed it as costly and unnecessary. They expressed a strong opinion in favour of constituting a public authority to acquire and manage the undertakings of the London water companies, and outlined the constitution of the suggested authority and the powers which should be entrusted to it.

A. J. M.

Water Supplies (Odours and Tastes in).—The causes of odours and tastes in water supplies and the methods of prevention have

FIG. 1.—*Synura*, magnified 500 dia. Free-swimming colony of from 10 to 50 biciliated individuals.

not generally received the full amount of attention the importance of the subject deserves. Many engineers in charge of the working of water supply systems are familiar with complaints from consumers in regard to smells from the water supplied, especially when heated, or in respect of unusual tastes occasionally noticeable in the same. Such complaints often occur at intermittent periods, and, in many cases, no proper explanation has been forthcoming owing to the difficulty of precisely identifying the true cause. Of recent years much light has been thrown upon the subject by a more systematic study of the microscopy of drinking waters, and it is now known that such odours and tastes are very frequently due to the periodic growth of minute vegetable and animal life in the water at its source. These periodic odours and tastes are to be distinguished from those which constantly obtain in a water, and which may be due to its geological source or

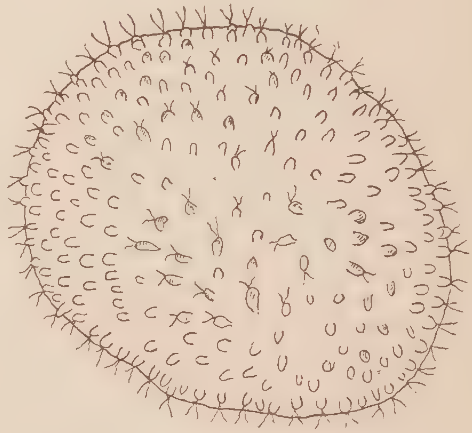


FIG. 2.—*Uroglena*, magnified 250 dia.

Uroglena, showing a single cell magnified 1,000 dia.

the dissolved mineral constituents it contains—for example, as in the case of brackish, chalybeate or mineral waters, such as those of Bath, Harrogate, and others. Chemically pure water is free from both odour and taste, but is not met with in nature. Many underground waters have either a saline or inky taste, and some a decidedly sulphurous odour, and gases may be given off in very perceptible quantities. Water from swampy ground or from thickly wooded catchment areas may yield a somewhat mouldy, woody, and unpleasant taste. Nearly all waters have some odour, though oftentimes it is too faint to be observed by the ordinary consumer. Roughly speaking, such odours may be due to the presence of organic matter other than living organisms, to the decomposition of organic

matter, or to the growth of living organisms, both animal and vegetable, in the water.

Odours derived from organic matter other than living organisms are in general of a vegetable origin, and are variously described by different observers as marshy, peaty, straw-like, woody, and such like. Heating the water generally intensifies the smell.

When vegetable or animal matter in water begins to decay very unpleasant odours are sometimes produced. These are commonly described as mouldy, fishy, musty, and so forth.

Of all the odours occurring in water supplies the most important are those due to the development of living organisms owing to their nature being oftentimes very offensive, and also to the fact that they frequently seriously affect large quantities of water, rendering it quite unsuited for public supply. In the writer's experience the rapid development of the diatom *asterionella* in a large open storage reservoir, in which a mixed supply of spring and underground water was unavoidably stored, rendered a large body of otherwise excellent water totally unfit for public supply, and also proved to be so prolific that the surface of sand filter beds became effectually blocked with the diatoms in the course of about 3 days' working. The surface film on the sand could then be rolled off like a carpet.

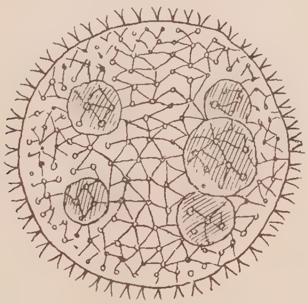


FIG. 3.—*Volvox*, magnified 80 dia.

Like most animals, different kinds of living organisms in water each have a natural characteristic smell, so much so, that experienced observers are able at once to identify the organism by the smell of the water. In a great many cases, and perhaps in all, the odour is due to the existence within the cells of the organism of minute oil globules, or compounds analogous to the essential oils, which are to be distinctly observed under

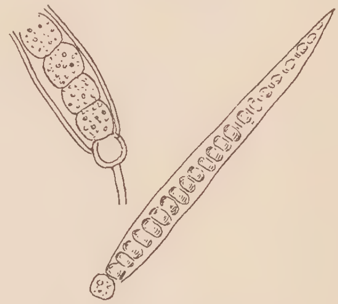


FIG. 4.—*Rivularia*, magnified about 500 dia.

suitable powers of the microscope. The oils are produced during the growth of the organism, are generally most numerous in mature forms, and oftentimes particularly so immediately preceding sporulation or encystment. The odour is intensified by any process

FIG. 5.—*Anabæna*, magnified 500 dia.

tending to break up the organism, such as mechanical agitation, increased pressure, pumping, or heating the water, as the "oils" thereby become liberated and dispersed throughout the water. This natural odour of the oil globules of the organism, the

production of which represents a kind of storing up of energy, is to be clearly distinguished from the disagreeable odours produced by their decomposition. The organisms develop most luxuriantly in quiet reservoirs, ponds, or backwaters, and are oftentimes attached in great quantities to the vegetation contained in the reservoir.

The odours commonly met with in water supplies are very variable and are difficult to describe. A few of those which are fairly well defined together with the organism causing them are :—

Description of Natural Odour.	Organism Causing the Odour.
Ripe cucumber odour with bitter taste	Synura.
Fishy and oily odour	Uroglena.
Fishy	Volvox.
Mouldy and like freshly cut grass	Rivularia.
Mouldy and grassy — like nasturtiums	Anabæna.
First aromatic—geraniums—and with larger numbers of organisms strongly fishy ..	Asterionella.

A water may be odourless although containing large numbers of organisms. Most of the organisms produce oil at some stage of their growth, but the oils in some cases may be odourless. The aromatic odours are mostly

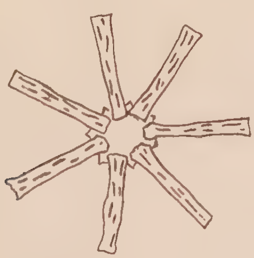


FIG. 6.—*Asterionella*, magnified 500 dia.

due to the diatomaceæ, the strongest smell being that derived from asterionella above referred to. Uroglena gives a very unpleasant odour ; it is quite common, and water impregnated with this organism smells fishy and something like cod-liver oil. The fishy odours are generally produced by organisms belonging to the animal kingdom.

The question naturally arises as to whether the drinking of water containing large quantities of living organisms is injurious to health. This is a matter which cannot be very definitely answered, but from present information it is generally believed that such organisms are not injurious. At the same time, however, it appears more than probable that a change from the drinking of pure water to the use of one highly charged with microscopic growths may at least give rise to temporary intestinal disorders, especially in the case of invalids and young children.

The question of the removal of microorganisms from large quantities of drinking waters is a matter of some difficulty, and, in many cases, of almost impossibility except by the slow operation of the ordinary processes of nature. Ordinary sand filtration is not always successful, as the odour-producing substances may sometimes pass through the filters unchanged. Also, large quantities of microscopic material rapidly accumulates by deposit and by increased growth upon the surface of the filter beds, causing prohibitive expense in cleansing the same. The best course to adopt, wherever possible, is to take steps to prevent the development of such growths by avoiding the conditions which have proved favourable to the multiplication of the organisms. For example, in the writer's experience, the open storage of deep well or underground water together with surface or spring waters produces at certain periods very troublesome growths of asterionella which may seriously interrupt the entire town supply. This has been completely overcome by the installation of mechanical filters to deal direct with the underground water (which, in the case in point, contains iron in solution), and storing the top waters only in open reservoirs pending sand filtration in the ordinary way.

W. H. M.

Water-Wheels.—Water-wheels are seldom installed now, but so many remain in use and

they are so well suited for driving pumps, without the intervention of gearing, that the main features of the various types may be shortly considered. These may be broadly classed as "undershot," "overshot," and "breast"—terms derived from the manner in which the water is applied to them. The undershot wheel is driven by the impulse of the water upon "floats" or paddles radiating from its circumference. Such wheels were originally placed in mid-stream with their floats dipping into it. An improvement consisted in damming the stream and providing a sluice at the bottom, through which the water issued and impinged upon the floats with a velocity proportionate to the "head" behind the dam. By setting the floats at a tangent to the circumference better results were obtained, but the greatest advance was made by Poncelet, who curved the floats and wheel-race and thereby realised about 60 °/o of the theoretical power of the waterfall, and efficiency of twice that of the common undershot wheel. The "Poncelet" (which is strictly speaking a kind of "impulse" turbine) is a very suitable water-wheel for falls up to about 6 ft. In the overshot wheel the water is carried over the top by a "pentrough" from the open end of which it discharges into buckets placed around the circumference of the wheel. An overshot wheel thus acts entirely by gravity, the unbalanced weight of the water in the descending buckets causing a preponderance on that side of the wheel and consequently its rotation. The chief sources of loss are due to the fact that the wheel, in order to clear the bottom of the pentrough and back-water in the tail race, must be less in diameter than the height of the fall, and also that the buckets are emptied before they have completed their descent. The highest efficiency obtainable is about 70 °/o.

In the "pitchback" wheel the diameter exceeds the height of the fall, and the pentrough, instead of being taken over the wheel, discharges the water on to its shoulder; the leverage at the commencement is, therefore, more advantageous than with an overshot wheel, but the slight gain involves a larger and more expensive wheel. With the old form of breast wheel the water acts both by impulse and gravity. In construction it differs from the undershot in not having wide open spaces between the floats on the circumference of the framing; in fact, the floats serve as buckets, the water being retained in them by the walls between which the wheel works and the concave "breasting" (of brickwork or masonry) embracing a portion of the periphery, until its escape into the tail race is permitted. It is now usual to fit buckets similar to those of an overshot wheel. The "hatch" or sluice by which the supply is regulated is now so arranged that the water flows over instead of under it as formerly; by this means every inch of "head" is utilised, and the water, acting entirely by gravity, is used to better advantage.

Breast wheels may be classed as "high" or "low," according to whether the water is applied above or below the horizontal centre line of the wheel. Until the advent of the turbine, the breast wheel was the most efficient for utilising falls of moderate head. These conditions so often exist in this country that breast wheels have received a great deal of attention and have been brought to a high degree of efficiency. This varies from 55 °/o for the low breast up to 70 °/o, and in some cases 75 °/o, for the high breast. The large size of a water-wheel in relation to the power developed renders the first cost high; this is also increased by the massive gearing necessary to impart the requisite speed to the machinery. Further they are seriously affected by floods, as the floats or buckets have to be driven through the back-water. (*See* "Water Power," "Turbines.")

E. L. B.

Webster's Process of Sewage Purification by "Electrolysis.—The precipitation of sewage by "electrolysis" has been successfully tried at Crossness, near the southern outfall of the Metropolitan sewage. By this system

the sewage is passed through channels between iron electrodes, whereby the chlorides are electrolysed and the sewage is deodorised by the chlorine and oxygen set free at the positive pole of the electrode, and the iron salts formed also assist in the purification of the sewage. It appears that the treatment produces a reduction in the oxidable matter in the sewage of from 60 to 80 °/ₒ. A risk of a direct process such as electrolysis would seem to be that the effective action may be only local, and that sewage may pass between the electrodes without much purification.

Wells and Well Supplies.—Wells of different kinds are named according to their depth, size, mode of sinking, and so forth, *e.g.*, shallow wells, subsoil wells, dip-wells and draw-wells, deep wells, Abyssinian or tube wells, and artesian wells or borings.

Shallow Wells are those entirely contained in a superficial bed of gravel or sand, and fed by land soakage and surface springs, which may fail in dry weather. The water is either dipped, raised by hand or by a suction pump. In the sixth report of the Rivers Pollution Commissioners, the shallow wells examined were under 50 ft. in depth, and the deep wells generally over 100 ft. deep; nevertheless, a well completely contained in a superficial stratum of sand or gravel may be actually deeper than a so-called "deep" well, which has pierced a regular geological stratum such as the chalk or new red sandstone. Deep well water is generally looked upon as one of the purest waters obtainable for public supply, except when containing mineral salts in objectionable quantities. The salts present will depend more upon the strata through which the water has percolated than upon its original source. Deep well waters often contain a large amount of iron and are frequently somewhat deficient in aëration. In such a case the water should be discharged in a cascade over a bell-mouth pipe, or down a series of steps in order to effect a thorough aëration, and so hasten the precipitation of the iron. It may also be treated for the removal of iron by means of the Candy oxidising pressure filters (*see* "Mechanical Filtration"). Excellent deep well supplies have been obtained from the new red sandstone by Birmingham, Liverpool, and many other towns, and from the chalk by Brighton, Margate, Eastbourne, and other places. Hastings obtains its deep well supplies from the Ashdown Sands, the water there being highly impregnated with iron.

The chalk supplies are obtained by large wells some 10 or 12 ft. in diameter sunk in the chalk, and having "adits" or headings driven in different directions from the base of the well so as to intercept the water-bearing fissures and create a large reserve of underground storage.

Deep Borings in the new red sandstone, Ashdown sands, and other strata are frequently drilled through the rock to considerable depths by special boring machines, and are lined as sunk with lengths of steel tubing screwed together, the lower lengths of tubing having a large number of perforations for the admission of the water. Such wells are bored to almost any requisite depth, from 3 in. up to 30 in. in diameter, and the water is often tapped under an artesian head, as, for example, is the case with many borings within the London basin.

When a deep boring is sunk through the London clay to the lower Tertiary sands or deeper into the underlying chalk, the water rises in the borehole, and, in some cases, even reaches the surface and overflows. The conditions under which such a circumstance arises will be apparent from an examination of Fig. 1, which is a geological section across the Thames basin, north to south, from the Chiltern Hills to the North Downs and Weald of Kent. If the water is tapped in low-lying ground as at *A* in the figure, which is in the hollow of the London basin, it is necessarily much below the level of the outcrop of the water-bearing strata at *B* and *C*, and the water will consequently be forced up the boring to its rest-level approximating to that in the surrounding strata. In some districts the

pressure of the underground water is such that it not only rises and overflows at the surface, but is forced into the air many feet, thus producing what is termed an "Artesian well" (*see* "ARTESIAN WELLS"). One of the most interesting of such wells is that at Bourn, in Lincolnshire, which supplies the town of Spalding. It was bored by C. Isler & Co., Southwark, in the Oolitic beds, and at the depth of 100 ft. it yielded a flow of 1,800 gallons per minute at a pressure of 10 lbs. to the square inch, reaching the ground surface with a rush. On sinking a further 34 ft. the flow was increased to 3,480 gallons per minute. In another boring (6 in. in diameter) by the same firm at Keighley, Yorkshire, sunk in the upper beds of the millstone grit, a supply of 15,000 gallons per hour was tapped, and the water rose to a height of 40 ft. above the surface.

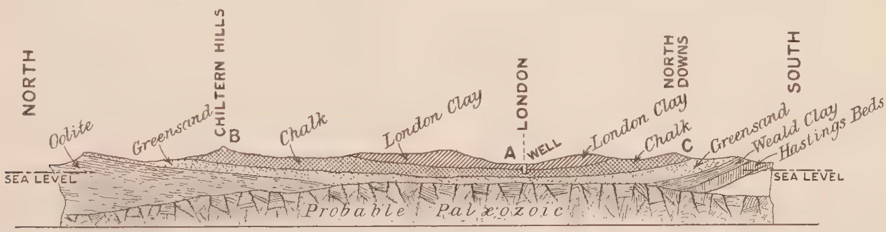


FIG. 1.—Geological Section across the Thames Basin from the Chiltern Hills to the Weald of Kent.

In the London basin the general rule is that in borings 400 ft. deep the water level is 100 to 200 ft. from the surface.

The fountains in Trafalgar Square are supplied from an artesian well penetrating to a depth of about 390 ft. below the surface, and numerous private supplies to breweries and other manufacturing establishments, as well as part of the supplies of some of the London water undertakings, are derived from the chalk underlying London. The effect of continually drawing large supplies from borings of this description is to lower the general level of underground water, and, unless adequately fed by the downward percolation of fresh supplies, to gradually deplete the storage of subterranean water.

In England the most favourable strata for deep wells are the chalk, oolites, new red sandstone, and the lower greensand. The yield will depend on the extent of the underground reservoir, the area of the outcrop of the water-bearing strata, its porosity or degree to which it admits of percolation of rainfall, and other considerations (*see* "UNDERGROUND WATER").

SHALLOW WELLS.—In rural districts good water may oftentimes be obtained from a shallow well, provided the requisite precautions are taken in the construction to insure protection from contamination and surface washings. The sides of such a well should be lined with brickwork set in cement, outside of which should be a thickness of impervious clay puddle extending downwards for about two-thirds of the depth of the well, or as circumstances may require. The brick lining should

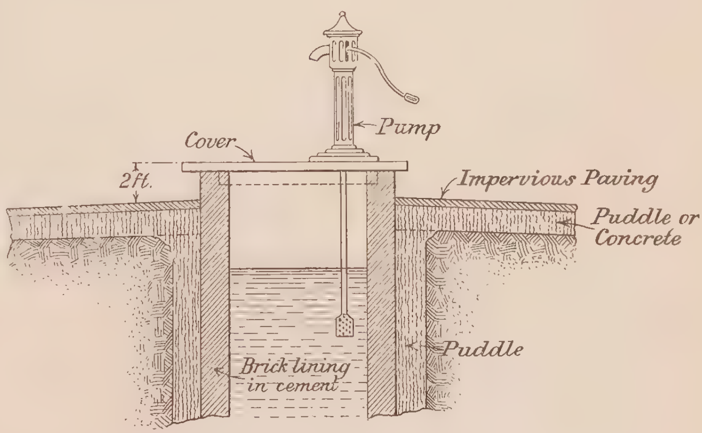


FIG. 2.—Section showing Top Part of Shallow Well.

also be carried up 2 or 3 ft. above the adjoining ground surface and fitted with a good cover, to prevent rubbish, animals, &c., from falling into the well. The ground around the well should also be paved with some impervious paving, as asphalte or concrete, and sloped away as shown in Fig. 2, so that no top soakage may gain access. For drawing the water a pump is much to be preferred to the old-fashioned bucket and windlass, as the well can be kept permanently covered

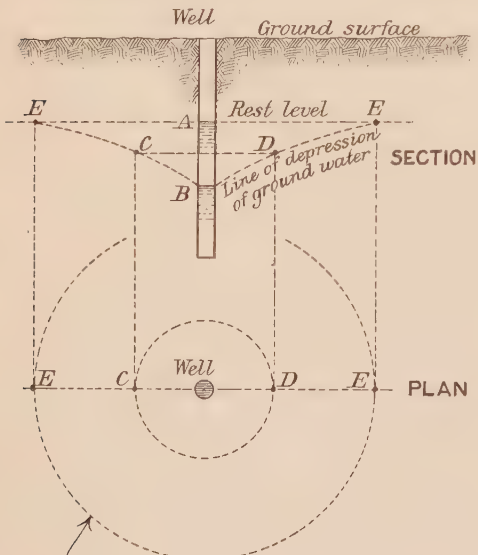


FIG. 3.

and the water is not disturbed and exposed to pollution to the same extent. In spite of precautions, however, all wells may at times become polluted if situate near cesspools or other accumulations of filth. Much depends on the direction of flow of the ground water. If this becomes polluted by leakage from a defective cesspool or drain and the ground water flows in the direction of a well, the water therein will naturally acquire dangerous properties, and in this way the germs of typhoid, for example, may be conveyed from cesspool to well, and the disease thus rapidly spread throughout the area supplied from this source. Numerous cases of this kind have been met with in practice. The risks of such pollution are always greatest after heavy rainfalls, when the level of the ground water is high and more likely to be brought into immediate contact with leakage from cesspools, &c.

Pumping from a well draws down the level of the underground water around the site of the well somewhat in the manner illustrated in Fig. 3, where *A B* is assumed to be the extent of the depression from "rest level." This influence is communicated in all directions from the site, and the slope of the lines of depression *B C E* and *B D E* will depend largely upon the porosity or permeability of the surrounding strata. The distances from which underground water is thus drawn often extend to many miles radius, and are expressed in terms of the depression. In chalk the distance may amount to 57 times the depression of the water level in the well, and in coarse gravel the distance affected is as much as 160 times the depression. Very much will depend, however, on the nature of the strata in any individual case. (For further information *see also articles* "ARTESIAN WELLS," "ABYSSINIAN WELLS," "WATER SUPPLY," and "UNDERGROUND WATER.") W. H. M.

White Lead.—This is hydrocarbonate of lead made by exposing metallic lead to the fumes of carbonic acid gas and acetic acid. The ancient "stack" process is usually recognised as yielding the best results, notwithstanding all attempts at improvement. The metallic lead is cast in the form of wickets not unlike a miniature gate in shape. Pots containing acetic acid are arranged close together on a platform covered with spent tan, and these wickets are strewn indiscriminately upon the pots. A second platform is built immediately above, and upon it the pots and wickets are placed, and so on until the top of the chamber is reached. The chamber is then closed in so that the fumes cannot escape, and after a period of three months the metal wickets are converted into a white lead. These are then taken out, passed through mills,

washed, ground and dried, and finally again ground in oil, when the white lead is ready for painters' use. English white lead is probably the best in the world. There is a good deal of white lead made abroad coarsely ground and brought to this country and ground here and then sold as "English manufacture." In specifying white lead it is advisable, therefore, to state that it is to be "English corroded." Adulterated white lead is either marked "reduced," or No. 1, No. 2, &c. Pure lead is always marked "Genuine," and if contained in an unbroken package one may be reasonably sure the contents are as represented.

Whittaker & Bryant Filter.—The Whittaker & Bryant "thermal aërobic filter" was introduced at Accrington in 1898. Septic tank liquor was distributed over a filter consisting of 1 ft. of limestone chippings at the top, 6 ft. of gas coke, and 2 ft. broken stone by means of a revolving distributor. A distinctive feature of the system consists in the use of a steam pipe in the delivery of the sprinkler. A small jet of steam is injected into the sewage as it arrives at the distributor with the object of raising the temperature of the sewage and filter generally to a suitable degree for rapid bacterial action. The artificial heat is also intended to induce air currents through the filter and thus create better aëration. Filters of this description have also been successfully tried at Leeds.

Wind Force.—The force of the wind is usually estimated without instruments according to Admiral Beaufort's scale. This scale, with the generally accepted equivalent velocity in miles per hour, is as follows :—

Scale.	Description of Wind.	Equivalent Velocity.
0	Calm . . .	0 miles per hour
1	Light air .	1—3 ,, ,,
2	Light breeze	4—7 ,, ,,
3	Gentle ,,	8—12 ,, ,,
4	Moderate ,,	13—18 ,, ,,
5	Fresh ,,	19—24 ,, ,,
6	Strong ,,	25—31 ,, ,,
7	Moderate gale	32—38 ,, ,,
8	Fresh gale	39—46 miles per hour
9	Strong ,,	47—54 ,, ,,
10	Whole ,,	55—63 ,, ,,
11	Storm	64—75 ,, ,,
12	Hurricane	above 75 ,, ,,

The best instrument for recording the force of the wind is Dines' Pressure-tube Anemometer. In this advantage is taken of the fact that the air, in blowing over an obstacle, produces small differences of pressure on various sides of the obstacle, which are capable of exact measurement, and afford information of the velocity of the wind. The "head" consists of a piece of tube open at one end, which end is kept facing the wind by a vane. The wind blowing into the tube produces an excess of pressure within it. There is also a piece of tube placed vertically and pierced by a ring of small holes. The wind blowing over these holes produces a slight decrease of pressure inside. These differences of pressure are communicated by composition tubing, which may be of any length, to the place where the recording part of the instrument is placed. The registration is produced by means of a bell-shaped vessel which floats inverted in water in a closed chamber. The pressure tube, *i.e.*, the tube coming from the "head" in which there is an excess of pressure, opens above the water-level inside the inverted floating vessel, and the other tube, *i.e.*, that in which there is a decrease of pressure, communicates with the sealed chamber. Very trifling differences of pressure are sufficient to alter the level at which the inverted vessel floats, and a pen rigidly attached to the vessel makes a continuous record on a clock drum in the usual way. The charts are arranged to give both the wind velocity in miles per hour and the wind pressure in pounds per square foot. In the Osler Anemometer the pressure of the wind in pounds per square foot is recorded by its action on a circular plate mounted on spiral springs and kept facing the wind by the vane. During gales the wind attains a high velocity, the greatest recorded in 1 hour being between 77 and 80 miles at

Fleetwood. In gusts, however, the velocity of the wind may momentarily exceed the rate of 100 miles an hour. W. M.

Wind Motors.—Although the familiar four-armed windmill is becoming a thing of the past, employment of the wind as a motive power for pumping, &c., is extending. At exposed sites in this country, a wind of not less than 15 miles an hour may generally be expected to prevail for about one-third of the year, whilst for about half the year it will be 10 miles and over; but it is often below the latter velocity for from 3 to 5 days, and occasionally a week. These points, however, can only be satisfactorily elucidated by local observations. Wind engines, when lightly loaded, will run with a breeze of less than 10 miles an hour, but as the power of wind varies as the cube of its velocity, their performance would be exceedingly small. For the same reason the great increase of power due to winds of a higher velocity than about 20 miles an hour has usually to be run to waste. The modern wind engine has, relatively, more than twice as much sail area as a four-armed windmill, but it only runs at about half the speed, so that the surface is used to less advantage. Owing, however, to its low speed, the vanes of a wind wheel may be set at a much greater angle with the plane of its revolution, and this, coupled with the large sail area, gives it a much higher starting "torque," and enables it to work in lighter winds than would suffice for the old-fashioned mill. In a good breeze, the power of either type, diameter for diameter, is much the same. The proportions of four-armed windmills vary considerably, but the following represents good practice. The breadth of the sweep is usually about one-fifth of its radius, which is commonly from 30 ft. to 40 ft.; the sail surface, in the direction of its length, is generally divided in the proportion of three to one by the "whip" or radial arm, the narrow portion moving foremost. The "weather" angle of the inner end of the wide part varies from 20° to 25° with the plane of motion according to the length of the sail; in some cases the angle gradually diminishes until it becomes about 7° at the outer extremity, but with cloth sails, to avoid flapping (and often with shuttered sweeps), the tip is made to coincide with the plane of motion. In this case the sail rapidly hollows inwards from the tip in order that an effective angle may be reached as soon as possible. The "lead," or narrow portion of the sail, usually preserves throughout its length the same angle as the inner end of the sail. The best tip speed is about two-and-a-half times that of the wind, and in a 15 mile wind each 75 ft. of sail surface should give about 1 h.p. actual, and assuming that the speed ratio of the sails to the wind may remain constant, the power will increase nearly as the cube of the wind velocity. The wind wheel has its vanes arranged in an annulus, and their combined area is generally from 60 to 70 °/₀ of the total disc surface. The weather angle of the vanes varies from 30° to 40°, and is often uniform throughout their length. To produce 1 h.p. in a 15 mile wind from 110 ft. to 130 ft. of sail surface is required according to the design and size of the mill—the larger sizes being less efficient. The usual method of speed control is to allow the wheel to turn more or less obliquely to the wind according to its pressure; this is accomplished by a hinged rudder or tail vane which is maintained at right angles to the plane of the wheel by a weighted lever or spring. The axis of the wheel is parallel to, but not in line with, the rudder, so that, but for the action of the weighted lever, the wheel would throw out of the wind. Large wheels are usually regulated by altering the weathering of the vanes, automatically or otherwise, which are hinged for that purpose. (*See* "ANEMOMETER.") E. L. B.

Zinc.—Zinc is one of the metallic chemical elements, found to a limited extent in England as zinc sulphide, called "zinc blende" or "black jack." The metal is usually extracted by the Belgian process as follows:—The

mixed ore and coal are put into fireclay cylinders of about 8 in. diameter and 3 ft. long, closed at one end; from 40 to 80 of these cylinders are ranged in a furnace like gas retorts. The carbon of the coal unites with the oxide of the zinc and escapes as carbonic oxide, leaving the metallic zinc to come off as a dense vapour. This is condensed in cast-iron conical tubes, from which it is raked out into a large iron ladle; the zinc is then skimmed from the dross and cast into ingots of 70 lbs. to 80 lbs. each. Zinc is pliable and moderately soft; at a temperature of 200° to 250° F. it is rendered malleable, and may be rolled into thin sheets. For this purpose the crude ingots are re-melted and cast into purer ingots of convenient size for rolling and passed between cast-iron rolls. Sheet zinc is extensively employed for cheap gutters, small rain-water pipes, lining wood cisterns, and covering flat roofs. It resists the action of pure air and moisture, but the air of towns, being heavily charged with acids, acts freely upon it and destroys it rapidly. It has one serious defect for roofs, as it blazes fiercely under the action of fire. Zinc, although supposed to be very light, weighs the same as cast iron—a square foot 1 in. thick weighs $37\frac{1}{2}$ lbs. There is a zinc gauge differing from the standard gauge, and still sometimes used: No. 12 Z.G., ·025 in. thick, is used for flashings; No. 14, ·031 in. thick, for dormers and flats; No. 16, ·041 in. thick, for gutters. Zinc when alloyed with twice its weight of copper forms yellow brass, but zinc enters into the composition of many alloys in the bronze series as well as the brass series. The terms "higher" and "lower" applied to brass express the greater or less quantity of zinc in the composition. The effect of zinc in an alloy in small quantity is to increase the fusibility without reducing the hardness, in larger quantity it increases the malleability when cold, but entirely prevents forging when hot; 1 to 2 °/₀ of zinc enables sounder castings to be made. Zinc is brittle when cold, and again at 400° F., but it is malleable at 212° F. Galvanised iron is sheet iron, corrugated or plain, coated with zinc by immersing it, when thoroughly cleansed, into a bath of melted zinc covered with powdered sal ammoniac. Galvanised iron forms a cheap covering for the sides and roofs of sheds, and is very largely used in new countries. The sheets are 6 or 8 ft. long, 3 ft. 2 in. wide before corrugation, 2 ft. 6 in. wide with 5 in. corrugations, and the depth of corrugation is a quarter of the width. It is laid with 6 in. laps when on the slope, 3 in. when vertical. No. 16 standard gauge is the thickness used where great strength is required, 17 to 19 for first-class work generally, 20 to 22 for ordinary work, 23 to 26 with 3 in. flutes for shipping abroad.

H. A.

Zinc Oxide (known as Zinc White).—A valuable pigment used in paint. It owes its increasing use to the fact that it is non-toxic and is not susceptible to the influence of sulphur compounds, as white lead is. It is a pure white, is very durable, and has a large covering capacity when ground in oil. (*See* "PAINTS AND PAINTING.")

Zones of Supply.—A term used to indicate different levels or areas of pressure in the distribution of water. In districts of a very undulating character it sometimes becomes necessary to limit the water pressures in the supply mains in the lower parts of the town and at the same time to adopt means of augmenting those in the more elevated areas, thus creating "zones of pressure or supply," each being adjusted to the requirements of the portion of the district served. (*See* "WATER SUPPLY.")

Zymotic Diseases.—After Pasteur's discovery of the anthrax bacillus, and his demonstration that it was the specific cause of anthrax in man and animals, bacteriologists directed attention to certain other diseases, and it has since been ascertained that many of these are due to the infection of the system by micro-organisms. There are still others so closely allied in character to those known to

be caused by bacteria that there can be little doubt that they are due to a similar cause, but as yet the specific germ has not been discovered. Originally all such diseases were termed "zymotic," but of recent years there has been a tendency to abandon the term altogether or to restrict its use to the more acute specific fevers. The zymotic death-rate is still recorded by medical officers of health, and signifies the annual number of deaths per 1,000 population from the seven principal zymotic diseases, which are small-pox, diphtheria, scarlet fever, measles, whooping cough, typhoid (*q. v.*), and allied fevers and epidemic diarrhœa.

Other zymotic diseases are cholera (*q. v.*), influenza, plague, cerebro-spinal fever, German measles, mumps, erysipelas, yellow fever, tetanus, glanders, syphilis, gonorrhœa, leprosy, pneumonia, and tuberculosis. There are many others, such as rheumatic fever, which are almost certainly due to infection by micro-organisms, though absolute proofs are yet wanting. Certain of these diseases are notifiable. The Infectious Disease (Notification) Act, 1889, imposes an obligation upon medical men to notify to the local medical officer of health certain cases of infectious disease which occur in his practice as soon as he becomes aware that the patient is suffering from such disease. The diseases so notifiable are scarlet fever, diphtheria, small-pox, cholera, fevers (typhoid, typhus, continued and puerperal), and erysipelas; but measles, chicken-pox, phthisis, and other diseases may be scheduled by a local authority after certain formalities and with the consent of the Local Government Board. It is now fully recognised that these diseases are not caused by insanitary conditions. Such conditions greatly predispose persons living within their sphere of influence to attack, by reducing the vitality or disease-resisting power of the system, but unless the specific germ of a disease is present and in some way gains an entrance into the system that disease will not supervene. Where filth is prevalent, where overcrowding abounds, and especially where these are associated with poverty, the possibility of the germs of disease gaining access to the system is enormously increased, and it is the prevalence of zymotic diseases under such conditions that has led many to conclude that they are the only condition necessary for the causation of certain fevers. The subjoined table gives the death-rates per 1,000 population from all causes and from the principal zymotic diseases, including phthisis, for the last three completed decennia:—

	1861–70.	1871–81.	1881–91.	1891-1900.
All causes . . .	22·4	21·3	19.1	18·2
Small-pox	·16	·23	·04	·006
Measles	·44	·39	·44	·41
Scarlet fever	·93	·72	·33	·16
Diphtheria	·18	·12	·16	·26
Whooping cough . .	·53	·51	·45	·38
Fevers	·88	·48	·24	·25
Typhoid fever . .	—	·32	·20	·17
Diarrhœal diseases . .	1·06	·94	·67	·73
Phthisis	2·5	2·1	1·7	1·4

It will be observed that measles and diphtheria show no signs of decreasing; obviously, therefore, sanitary improvements have had no influence upon them, or if there has been any effect it is so masked by the other factors, such as enforced school attendance, as to be unrecognisable. The decreased prevalence of small-pox is chiefly attributable to the continued practice of vaccination. Scarlet fever mortality has decreased so rapidly and steadily that we might conclude improved sanitary conditions and the provision of isolation hospitals have had a most marked effect, but there are reasons for doubting whether such is the case. The type of the disease has been undergoing a continuous diminution in virulency, so that, although as many cases occur as heretofore, the mortality has fallen enormously. It is possible, however, that the more clean conditions which obtain and the isolation of the more severe cases have had a share in diminishing the virulency. That fevers have decreased to one-fourth is due to the greater attention paid to supplies of milk, water, and articles of food, to the diminution of

overcrowding, the demolition of slums, and the erection of workmen's dwellings, and to improved methods of sewerage and drainage. The reduction in the death-rate from diarrhœal diseases may be due to the same causes, but as very young children are the chief sufferers, and the mortality varies very largely from year to year according to the earth-temperature in the autumn, it is obvious that there are conditions, of which we are as yet ignorant, which influence the mortality from these diseases. The cause of the great and continuous decrease in the mortality from phthisis is one of the enigmas of public health. The drying of the subsoil by the sewerage of towns, the prevention of damp in houses by enforcing proper building by-laws, are possibly important factors. Small-pox, measles, scarlet fever, diphtheria, whooping cough, and typhus fever are diseases which are spread by the inhalation of the breath of infected persons and by the inhalation of minute particles of sputum discharged by infected persons when coughing. The infection of typhus fever and small-pox also appears to be capable of being given off from the skin. Obviously, therefore, there is less danger of these diseases being disseminated in roomy and well ventilated houses than in small badly ventilated and overcrowded dwellings.

Outbreaks of scarlet fever, typhoid fever, and diphtheria have frequently been traced to milk, though how the milk became infected has not always been discovered. Generally, however, it has been found that some person suffering from one of these diseases has been employed in the cowsheds or dairy from which the implicated milk was derived.

Typhoid fever and cholera are chiefly water-borne diseases, but any article of food may become infected, and convey the diseases. The germs of these diseases are chiefly voided in the stools, and in typhoid fever the patient's urine often swarms with the specific bacteria. Hence the great danger arising from the use of privies and pail closets, of water-closets without proper flushing apparatus, from accumulation of house refuse and from defective paving around yard gullies. Infection under such circumstances may easily be conveyed by flies or by wind to exposed articles of food, and spread of the disease results.

It is fortunate for the human race that the mere presence of a few of these germs in the system rarely suffices to set up disease, otherwise man would have been exterminated long ago. The blood possesses certain germicidal powers, and when vitality is unimpaired, germs entering the system, if not in excessive number, may be destroyed. Where it is necessary for the microbes to gain access to the blood stream before they can produce any evil effects it is quite possible for them to pass through the alimentary canal and fail to enter the system. The blood also possesses to some extent the power of destroying the toxins or poisonous bodies formed during the growth of disease-producing bacteria. These properties explain why, when large numbers of persons partake of specifically infected water or milk, only a small proportion, as a rule, are actually attacked by disease. (*Vide* "Germs of Disease.")

J. C. T.

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Sewerage and Sewage Disposal.

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—— **Sewerage and Sewage Purification.** *Fourth Edition, revised and enlarged.* 16mo., boards, 161 pp. (Van Nostrand Science Series No. 18.) New York, 1907 .... 50 cents

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